Senator George J. Mitchell Center
Annual Technical Report
FY 2012

Introduction

The Maine Water Resources Research Institute (Maine Institute) is the primary locus that sustains water science in the state through its support of research, graduate studies, and outreach. These fundamental and essential functions, which would not exist without Congressional authorization and appropriations, are not duplicated in the state in any other form. The federal money that supports the Water Resources Research Institute is highly leveraged with other funds provided by stakeholders, universities, and researchers. Research project proposals are evaluated by peer-review and approved by our Research Advisory Board composed of members from the U.S.G.S. Water Science Center, State Environmental Agencies, U.S. EPA, academia, and industry. During the FY12 period, the Maine Institute supported six (6) research projects, including three student-directed projects: (1) Detection and removal of PPCP's from water supplies; (2) Mercury informatics for aquatic systems; (3) Contributions of street dust to degraded urban streams; (4) Coastal effects on mercury in freshwater fish; and (5) Quality assurance of student scientist data (well water) to improve trust. The Maine Institute supported additional Information Transfer activities such as working with municipalities to manage salt to protect water quality, the Maine Water Conference and GET WET! activities. These projects directly supported four graduate students and three undergraduate students.

The Maine Institute Director, John Peckenham, also serves as the Associate Director of the Senator George J. Mitchell Center. The Mitchell Center provides the administrative home for the Institute. This structural association greatly enhances our efforts to have the Maine Institute increase the breadth and accessibility of water research in Maine. The Mitchell Center is the recipient of a five-year EPSCoR grant from the National Science Foundation to develop the Sustainability Solutions Initiative. This grant is fostering even greater multi-institutional, interdisciplinary research projects, including several projects related to water resources.

The 19th annual Maine Water Conference was held in March and continues to be the most important regional event for the water community. The number of people and organizations who support and contribute to this conference reflects the importance of water to the people of the State of Maine. Through the hard work of Mitchell Center staff, the Conference Steering Committee, and major supporters, we have been able to address the important water issues in Maine and to bring together diverse interest groups.

The Water Resources Research Institute's affiliation with the Mitchell Center gives us the ability to support both large and small projects that address important local needs. It also provides us leverage to develop and attract funding from other agencies. This program is strongly supported by UMaine's Vice President for Research who contributes $50,000 annually to the 104b research projects. In FY12, the Maine Institute had projects that brought in other funds from state agencies (e.g. Department of Inland Fish and Wildlife, Department of Environmental Protection), federal agencies (e.g. U.S. Fish and Wildlife, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Agency), and foundations. None of these projects would be possible without the support of the federal Water Resources Research Institutes program and the U.S. Geological Survey.

Research Program Introduction

The Maine Water Resources Research Institute supports research and information transfer projects using 104b funds. Projects are awarded on a competitive basis using a two-stage selection process. The Research Advisory Committee, comprised of the Institute Director, Regional U.S.G.S. Chief Scientist, state and federal agency representatives, and water resources professionals, set the research priorities based on current state needs and issues. The Institute issues a call for pre-proposals in the spring. The pre-proposals are reviewed by the Executive Committee (5 individuals) and full proposals are solicited for 150% of available funds. Full proposals are sent out for external review (out-of-state reviewers are required). The full Research Advisory Committee (12 members) reads the proposals and reviews to provide the Institute Director with a selection of proposals to fund. Much effort is made to solicit suggestions for themes, to diversify the types of projects funded, and to include researchers from the small colleges and universities in the state. Preference is given to support new faculty and projects developed by students. Investigators are encouraged to collaborate with state and federal agencies and to seek additional contributions for their projects.

In consultation with our Research Advisory Committee, we include students in our general call for proposals. Response to this student-centered program has been strong and it will be continued.

Investigating the Impact of Pollutants in Street Dust on the Long Creek Watershed, South Portland, ME: Collaborative Research Between USM, CCSWCD, and LCWMD

Basic Information

Title:	Investigating the Impact of Pollutants in Street Dust on the Long Creek Watershed, South Portland, ME: Collaborative Research Between USM, CCSWCD, and LCWMD
Project Number:	2012ME256B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	first
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Education
Descriptors:	None
Principal Investigators:	Lucille Benedict, Kate McDonald

Publications

There are no publications.

Investigating the Impact of Pollutants in Street Dust on the Long Creek Watershed, South Portland, ME: Collaborative Research between USM, CCSWCD, and LCWMD

Lucille A. Benedict[1], Kate McDonald[2]
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[2]Cumberland County Soil and Water Conservation District, Windham, ME

General Results

This collaborative undergraduate research project between USM, Cumberland County Soil & Water Conservation District (CCSWCD) and Long Creek Watershed Management District (LCWMD) is dedicated to exploring the concentrations, trends, and fate and transport of chloride, metals, and PAHs in street dust and their effects on sediment and surface water quality within the Long Creek watershed. Over the past year 4 undergraduate students have worked on this project collecting samples, processing samples, and analyzing the data. In the summer of 2012 over 100 samples were collected in the Long Creek watershed that include monitoring site samples and samples from a day long sampling event. Data from the monitoring sites has been the focus of data analysis to this point in the research.

Data from street dust and catch basin samples collected from numerous locations in Long Creek, including four monitoring sites indicate that high levels of carcinogenic PAHs (cPAHs) as well as copper, zinc, and chromium are present in street dust samples. Levels of cPAHs were above the outdoor commercial worker Maine Remediation Action Guidelines (RAGs). This project investigated the effectiveness of periodic street sweeping on contaminant accumulation in street dust in the watershed and the extent of contamination in surface water and sediment from street dust.

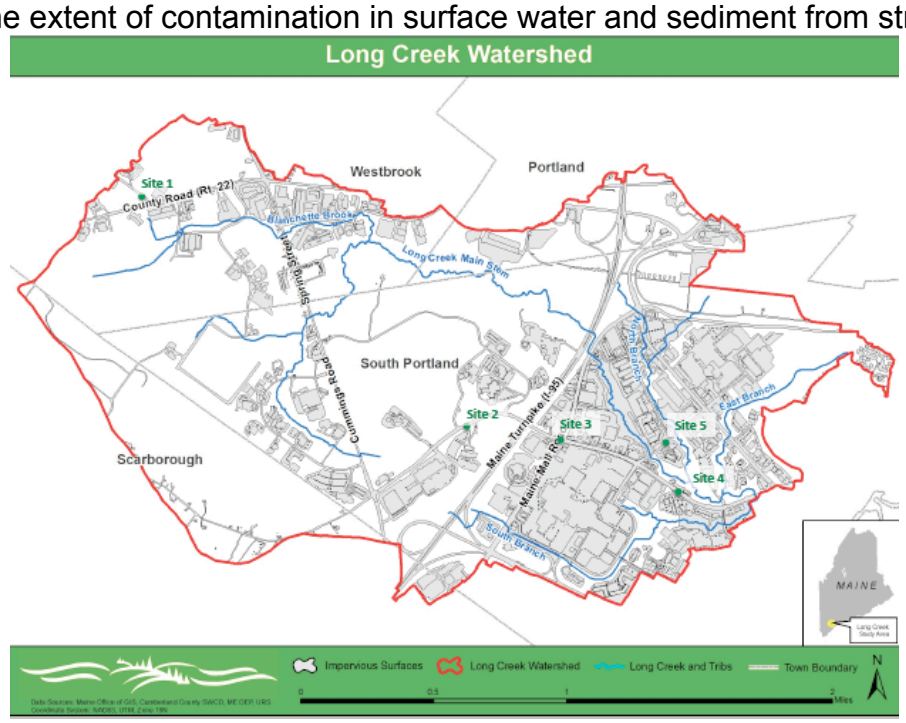

Figure 1. Map monitoring sites within the Long Creek watershed.

There is a great deal of variability in metals, chloride, and PAH concentrations at each monitoring site. When comparing the sites to each other it is evident that as traffic volume, and the amount of vehicles coming to a stop and starting up increases the levels of metals and PAHs increases.

		Cr	Cu	Zn	Pb	Cl	Br	TPAH
Site 1 (Background)	Mean (ppm)	65.7	21.1	76.6	28.6	147	0.67	33.4
	%RSD	31.0	41.0	78.4	13.9	117	50.3	118
	Max. (ppm)	145	60.0	378	43.4	663	1.5	102
	Min. (ppm)	35.1	12.3	45.7	23.1	20.6	0.3	3.78
Site 2	Mean (ppm)	159	54.3	294	42.8	1212	1.11	21.0
	%RSD	24.8	33.1	31.4	11.3	137	46.8	38.9
	Max. (ppm)	246	96.8	496	57.6	8030	1.9	34.0
	Min. (ppm)	74.9	22.5	116	32.3	205	0.3	11.4
	Contam. Ratio	2.4	2.6	3.8	1.5	8.2	1.7	0.63
Site 3	Mean (ppm)	167	88.6	314.7	42.0	848	1.34	492
	%RSD	28.2	49.1	44.3	14.5	125	46.9	98.0
	Max. (ppm)	265	199	705	53.5	5219	2.8	1591
	Min. (ppm)	58.6	23.1	73.9	27.3	55.5	0.3	52.4
	Contam. Ratio	2.5	4.2	4.1	1.5	5.8	2.0	15
Site 4	Mean (ppm)	170	54.4	218	39.2	712	1.05	46.3
	%RSD	23.6	35.5	30.8	11.5	100	79.1	153
	Max. (ppm)	268	107	453	47.0	3015	4.5	203
	Min. (ppm)	98.8	18.2	105	30.5	204	0.3	7.27
	Contam. Ratio	2.6	2.6	2.9	1.4	4.8	1.6	1.4
Site 5	Mean (ppm)	87.7	31.3	159	39.3	768	1.87	16.2
	%RSD	44.1	47.3	38.8	8.49	153	76.5	37.1
	Max. (ppm)	194	67.2	357	45.5	4305	5.4	26.2
	Min. (ppm)	52.6	16	98.7	32.6	94.2	0.4	7.68
	Contam. Ratio	1.3	1.5	2.1	1.4	5.2	2.8	0.48

Figure 2. Levels of metals, chloride, bromide, and TPAH (sum of 16 EPA priority PAHs). Contamination ratios (contam. ratio) were calculated by dividing the average concentration of each site with the average concentration of the background (Site 1).

PAHs

- Mean TPAH concentration at Site 3 is an order of magnitude greater than average levels at any other site. These levels are attributed to a high volume of traffic at the intersection, as well as the application of coal-tar sealant on a parking lot uphill of the sampling site.
- At Site 3 five PAHs (benzo[a]anthracene, benzo[b]fluoranthene, benzo[a]pyrene, diben(a,h)anthracene, indeno(1,2,3-cd)pyrene) exceeded the Maine Regulatory Guidelines (RAGs) on the week of and the week directly after the application of coal-tar sealant on a near-by parking lot (4/28 & 5/3).
  Throughout the sampling benzon[a]pyrene remained above RAG levels.

Metals

- Sites 1 and 5 generally had the lowest concentrations of Cr, Cu, Zn, and Pb over the time of this study.

- Sites 2, 3, and 4 show an increase in these metals from April until August, and then a decrease from September to February, possibly due to changes in traffic volumes.

Chloride

- Chloride shows the opposite trend of the metals, with highest levels dominantly in April, and from November through February, likely due to salting for the roads during storm events.

Based upon the data, sweeping of areas with high volumes of traffic and regular stopping and starting of cars would have the largest impact on limiting the levels of these contaminants reaching Long Creek. The timing and frequency of sweeping should also be focus between June and September when levels of metals and PAHs are highest. This data will be added to the Long Creek Watershed Management District's database and will be used in the future to aide in decisions on street dust management.

Future Work

In the summer of 2013 we will continue the collection of samples from the monitoring sites in Long Creek. These samples will all be analyzed for metals, and that data will continue to be shared with LCWMD. Samples from the bulk sampling even have been analyzed for metals, the data will be analyzed over the summer. PAH analysis on the rest of the samples collected in 2012 will continue as well this summer and into the fall.

LCWMD and USM are working on a publication to submit in the Fall of 2013 on the metal data collected.

Informatics approaches for reuse and modeling of heterogeneous mercury data

Basic Information

Title:	Informatics approaches for reuse and modeling of heterogeneous mercury data
Project Number:	2012ME260B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Maine 2nd
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Models, Toxic Substances
Descriptors:	None
Principal Investigators:	Kate Beard, Linda Bacon, Melinda Neville

Publications

There are no publications.

WRRI FY2012 Progress Report

Informatics approaches for reuse and modeling of heterogeneous mercury data

Project duration. September 1, 2012 to February 28, 2014

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Abstract.

The project funds supported a PhD student for the development of a database that synthesized two decades of coastal Maine mercury (Hg) research across many different sample media. In this stage of the project, the Mercury Research Ontology is being developed to facilitate comparison of the disparate datasets in a computer readable language. Ontologies foster data integration and reuse for geospatial modeling and prediction of Hg dynamics. The Hg ontology will support several key activities and goals, including an information 'blueprint' to support data collection and reporting with the use of common terms and controlled vocabularies, identifying data gaps, results of specific regulations, and potential areas of concern that warrant further data collection and analysis to inform decision making.

Project Status

We are currently assessing data quality and consistency and updating the established database with currently available data. The ontology development is proceeding with Neville learning OWL (Web Ontology Language) and using the Protégé Ontology editor. These tools are essential for documenting the base vocabulary for the Hg Research Ontology.

The ontology development is currently proceeding with the creation of two ontologies; one that is directly related to Hg fate and transport in the environment- essentially the formal specification of the sources and sinks present in the Hg cycle, and a second that describes cataloging and linking the research data, between projects as well as each datum location within the cycle ontology.

Next Steps

Collaboration with data producers is essential to fully describing the spatial, temporal, climatic, and landscape contexts appropriate for each dataset. Once we have more pieces of the "ontology puzzle" in place, we can start to test the competency of the ontologies. This will be the proofing stage, in which we query the system to ensure consistency in definitions and categorizations. Following the completion of this phase, will be hosting a workshop with local Hg researchers to further test and expand the ontologies.

Citations resulting from this work

Neville, M. 2013. Mercury (Hg) Research Ontology: Employing Informatics in Geochemistry. Presentations for the National Science Foundation IGERT 2013 Video & Poster Competition. April, 2013.

Neville, M. and Beard, K. 2013. Biogeochemical Informatics for Reuse and Modeling of Legacy Mercury Data. Poster Presentation at the Maine Water Conference, Augusta, ME. March 19, 2013.

Neville, M. 2012. Informatics Approaches for the Reuse and Modeling of Heterogeneous Mercury Data. National Water Quality Monitoring Council Conference, Portland, OR.

Photocatalytic Degradation of Pharmaceuticals and Personal Care Products (PPCPs) in Natural Water using Silver-Doped Zeolites

Basic Information

Title:	Photocatalytic Degradation of Pharmaceuticals and Personal Care Products (PPCPs) in Natural Water using Silver-Doped Zeolites
Project Number:	2012ME264B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Toxic Substances, Water Quality, Treatment
Descriptors:	None
Principal Investigators:	Aria Amirbahman, Howard Patterson

Publications

There are no publications.

Progress Report

Project Number: 2012ME264B

Title: Photocatalytic Degradation of Pharmaceuticals and Personal Care Products (PPCPs) in Natural Water using Silver-Doped Zeolites

Investigators: Aria Amirbahman, Zhong Pan and Howard Patterson

1. Problem and Research Objectives

Pharmaceuticals and personal care products (PPCPs) are a diverse group of compounds which include prescription, over-the-counter therapeutic drugs, veterinary drugs, fragrances, cosmetics, sun-screen products, diagnostic agents, nutraceuticals. A large number of various PPCPs consumed by both humans and animals each year is not completely assimilated, but excreted unchanged or as metabolites, back into aquatic environment. Most conventional wastewater treatment plants (WWTPs) have no specific designs to remove PPCPs. Therefore, the limitations of PPCPs elimination in WWTPs have turned these contaminants into a major emerging concern in U.S. water supplies. Nationwide investigations of the occurrence of PPCPs by the U.S. Geological Survey have shown the presence of PPCPs in the ng/L - mg/L concentration range in the effluents of WWTPs and river throughout the U.S. indicating the widespread prevalence and exposure concern of these contaminants.

Categorized as environmentally persistent and bioactive organic micropollutants, certain PPCPs may produce negative environmental effects even at very low levels. One such substance, the synthetic estrogen 17α-ethinylestradiol (EE2) at low (ppb) concentrations, can cause the feminization of male fish, altering the reproductive potential of the fish population. The effects of chronic low dose exposures of an individual PPCP on aquatic organisms are still largely unknown. As known or potential endocrine disrupting compounds (EDC), their continued introduction and frequent detection in surface waters affect water quality and produce negative impact on drinking water supplies, ecosystem and human health.

UV-assisted degradation is an important pathway for the removal of PPCPs in water. However, direct UV photolysis is a slow process that must be accelerated to be of any practical application. The particulate semiconductor titanium dioxide (TiO_2) has been extensively and successfully used in the laboratory and pilot studies as an efficient photo-catalyst owing to its high photocatalytic activity and low cost. However, TiO_2 has two major limitations that limit its application in large-scale water treatment: (a) TiO_2 particles without any support aggregate easily in suspension leading to a smaller effective surface area and lower catalytic efficiency; (b) Filtration efficiency is lowered due to difficulties encountered in the separation of TiO_2 particles. Thus, to circumvent these shortcomings, TiO_2 particles should be immobilized on a support or a carrier.

Zeolites are microporous, crystalline aluminosilicates minerals with well-defined pore and channel structures formed by the linkage of shared oxygen atoms from the XO_4 units, a large specific surface area (300~1090 m^2/g) and high sorption capacity, which make them ideal host materials for treatment of waters contaminated with PPCPs. In this research, the synthesized TiO_2-doped zeolites were used to investigate their photodegradation activity towards PPCPs. The photodegradation of EE2 in the presence of unsupported-TiO_2 and without adding any catalysts have also been performed in order to compare EE2 photodegradation efficiency under different experimental conditions. The results have shown improved photocatalytic performance in the degradation of EE2 using the zeolite-supported TiO_2.

In summary, the objectives of the project are:

- To examine the efficiency of TiO_2-doped zeolite for the degradation of the PPCPs listed in Table 1 using synchronous-scan fluorescence spectroscopy (SSFS) technique.
- To ensure that the catalysts can be regenerated rather than producing a secondary solid waste contamination.
- To propose photodegradation mechanisms of PPCPs using TiO_2-zeolite and identify degradation byproducts using HPLC/MS and density functional theory (DFT) molecular calculations.
- To apply the laboratory findings to field samples spiked with different concentrations of PPCPs from wastewater effluents in Old Town, Orono and Bangor WWTPs by using TiO_2-doped zeolites to degrade PPCPs under UV irradiation.

2. Methodology

2.1 Synthesis of low silica X zeolite (LSX) supported TiO_2 catalysts

LSX was synthesized using a modification of an existing method. Initial molar compositions in the starting gel were SiO_2: Al_2O_3: Na_2O: K_2O: H_2O = 2.2: 1: 5.005: 1.495: 110.5. In a typical synthesis, sodium aluminate ($NaAlO_2$) was dissolved in water with stirring. Sodium and potassium hydroxides were added in when the solution turned clear. The mixture was stirred until its temperature dropped below 40 ˚C, following which sodium silicate was slowly added. It took about 5 min for the starting solution to be clouded and gelled, leading to a highly viscous gel like solid. Aging and crystallization steps were performed at 70 ˚C for 24 h.

TiO_2/LSX was prepared by solid-state dispersion (SSD). At first, TiO_2 (7 wt.%) and LSX were thoroughly mixed using ethanol in an agate mortar and pestle. The solvent evaporated during mixing. Then samples were dried at 110 ˚C, followed by calcinations at 450 ˚C for 6 h.

2.2. Characterization of TiO_2/LSX catalysts

X-Ray Diffraction (XRD) scans were taken on the zeolites to verify the presence of metal or metal oxide on the zeolites. The prepared zeolites were characterized by a powder X-ray diffractometer (X'pert Pro, PANalytical) operated with a CuKα line at 45 kV of an acceleration voltage and 40 mA of a current. BET specific surface area measurements, micropore volume and total pore volume were obtained by measuring N_2 adsorption/desorption isotherms on an Autosorb®-iQ system (Quantachrome) at 77 K. FT-IR spectra were obtained at room temperature using a Perkin-Elmer Spectrum One FTIR spectrometer over the scan range of 4000~400 cm^{-1}. The frequency resolution used was 4 cm^{-1}, and a total of four scans were measured for each sample. Measurement of Ti content in the TiO_2/LSX was carried out using a Perkin Elmer 3300 XL ICP-AES (axial mode). 0.1 g/L TiO_2/LSX was dissolved in 10 mL of 25% trace metal grade HNO_3 for 24 h to break zeolite framework and extract metal ion completely prior to the ICP analysis. Ti content in the TiO_2/LSX was determined to be 0.7797 wt.% .

2.3. Photodegradation experiment

Photocatalytic experiments were conducted in the Rayonet photochemical chamber reactor (Model RPR-100) equipped with RPR-2537A˚ lamps emitting radiation in the UV-C range (~254 nm) from the Southern New England Ultraviolet Company, USA. The intensity of the reactor's UV lamp source was measured by the ferrioxalate actinometry method. Potassium ferrioxalate was used as the chemical actinometer and ferrozine method was used for determination of dissolved Fe(II).

The stock 100 ppm EE2 solution was prepared in a 20:80 v/v% methanol/water mixture. All diluted EE2 solutions were prepared immediately before irradiation experiments. A certain amount of catalyst was added to a 150 mL quartz vessel, following which 50 mL EE2 solution was added. Each experiment was performed in the presence 5×10^{-3} M carbonate pH buffer solution that also fixed the ionic strength. The suspensions were vigorously mixed using a magnetic stir bar throughout the experiments. The UV light intensity was adjusted by covering some of the lamps with aluminum foil. At various time intervals, the quartz vessel was removed from the UV chamber, 3~5 mL of solution was taken to pass through a 0.45 μm syringe filter, and measurements of fluorescence intensity of filtrate were recorded.

2.4. Synchronous-scan Fluorescence Spectroscopy

Photodegradation of EE2 was monitored with a Jobin Yvon Fluorolog-3 spectrofluorometer, which includes emission and excitation monochromators, a 400W Xenon lamp source, and a photomultiplier tube. Synchronous-scan fluorescence spectroscopy (SSFS) technique involves scanning both the excitation and emission

monochromators over a specified range of wavelengths by maintaining a constant wavelength difference ($\Delta\lambda$). A $\Delta\lambda$=30 nm, as the difference between the maximum emission and excitation wavelength for EE2, was used for synchronous scanning. A calibration check of the xenon lamp source and water Raman peak were routinely conducted. 10 mm quartz cuvettes were cleaned with DI water and starna cells brand cuvette cleaning solution (Starna Cells, Inc) between measurements.

2.5. HPLC/MS analysis

Liquid chromatography with electrospray-ionization mass spectrometry analysis was performed on an Agilent 6530 Accurate-Mass Q-TOF LC/MS system to identify the intermediate products. The mobile phase is set as gradient flow: 98% A and 2% B at t=0; at t=2 min, 50% A and 50% B; at t=9 min, 50% A and 50% B; at t=11min, 2% A and 98% B; at t=15 min, 2% A and 98% B; at t=15.1 min, 98% A and 2% B. A is 0.1% formic acid in water and B is 0.1% formic acid in acetonitrile. The injected volume was 2 μL.

2.6. Molecular calculation

The theoretical structure, electronic distribution, molecular orbitals of EE2 in different systems (EE2, EE2-zeolite, EE2-TiO_2 and EE2-TiO_2-zeolite) in the neutral, positive mono-cation, and negative mono-anion form are determined by Density functional theory (DFT) with hybrid B3LYP functional using Gaussian 09 program through the University of Maine Supercomputer Center. Atomic charges were calculated from Mulliken population analysis. The 6-31+G(d,p) basis set was used for C, H, O, Si, Al, and Ti atoms calculation. Isodensity representations of molecular orbitals were generated using GaussView 5.07 software.

3. Principal Findings

The effects of different UV light intensities, initial EE2 concentration, and catalyst dosage on the EE2 removal efficiency were studied and the results are reported in Table 1. In addition, photodegradation kinetics and parameters under UV alone, UV/TiO_2 and UV/TiO_2-LSX were analyzed and compared (Figure 1). The results demonstrated that a higher EE2 removal efficiency (more than 90% conversion after 20 min of UV irradiation) resulted in the presence of TiO_2-LSX than in the absence of this catalyst under the same photon flux.

As shown in Table 1, the photocatalytic degradation of 10 ppm EE2 was in accordance with pseudo-first-order kinetics under all UV intensities. The reported pseudo first-order rate constants (k values) indicate that EE2 degradation rate is directly proportional to the UV light intensity. EE2 degradation at different initial concentrations also followed pseudo first-order kinetics, but the associated rate constants decreased with increasing

initial concentration due to the introduction of inner filter effect. As expected, EE2 degradation rate increased with an increasing catalyst concentration and followed a pseudo first-order rate.

Table 1. Pseudo-first-order rate, half-life and photodegradation parameters

Factors	Values	k (min^{-1})	$t_{1/2}$(min)	R^2	Φ(mol $Einstein^{-1}$)
[a]UV intensity	1.26×10^{-5}	0.100	6.93	0.987	0.022
(Einstein/min)	2.56×10^{-5}	0.147	4.27	0.999	0.016
	4.05×10^{-5}	0.171	4.05	0.999	0.011
	5.32×10^{-5}	0.203	3.41	0.994	0.010
[b]Initial EE2 concentration	1	0.149	4.65	0.948	0.032
(ppm)	2	0.141	4.92	0.963	0.030
	5	0.143	4.85	0.989	0.031
	10	0.100	6.93	0.987	0.022
	20	0.053	13.08	0.957	0.019
	30	0.038	18.24	0.973	0.012
[c]TiO_2/LSX	0.01	0.025	27.73	0.988	0.005
(g/L)	0.05	0.040	17.33	0.981	0.009
	0.1	0.045	15.40	0.975	0.016
	0.2	0.053	13.08	0.981	0.019
	0.5	0.100	6.93	0.987	0.022

a. EE2 concentration: 10 ppm; 0.5 g/L TiO_2/LSX; 0.001 M carbonate buffer
b. UV intensity: 1.26×10^{-5} einstein/min; 0.5 g/L TiO2/LSX; 0.001 M carbonate buffer
c. UV intensity: 1.26×10^{-5} einstein/min; EE2 concentration: 10 ppm; 0.001 M carbonate buffer

Using multiple linear regression analysis, we have developed a model that successfully describes the EE2 degradation kinetics under all initial EE2 concentrations, UV intensities and LSX loadings (results not shown here). Additionally, our work has shown that TiO_2-doped LSX can be recycled for reuse without compromising its photocatalytic activity; reusing the same TiO_2-doped LSX batch resulted in similar EE2 photodegradation rate.

TiO_2-doped LSX also helped to resolve the problems TiO_2 encounters today such as easy aggregation and difficult separation after treatment. Currently limited design and ineffective techniques in WWTPs lead to emerging concerns of prevalence of PPCPs including EE2 in the wastewater effluent and receiving waters. The novel TiO_2-doped zeolite system we developed in this study will provide a promising application in the UV disinfection process in WWTPs in future.

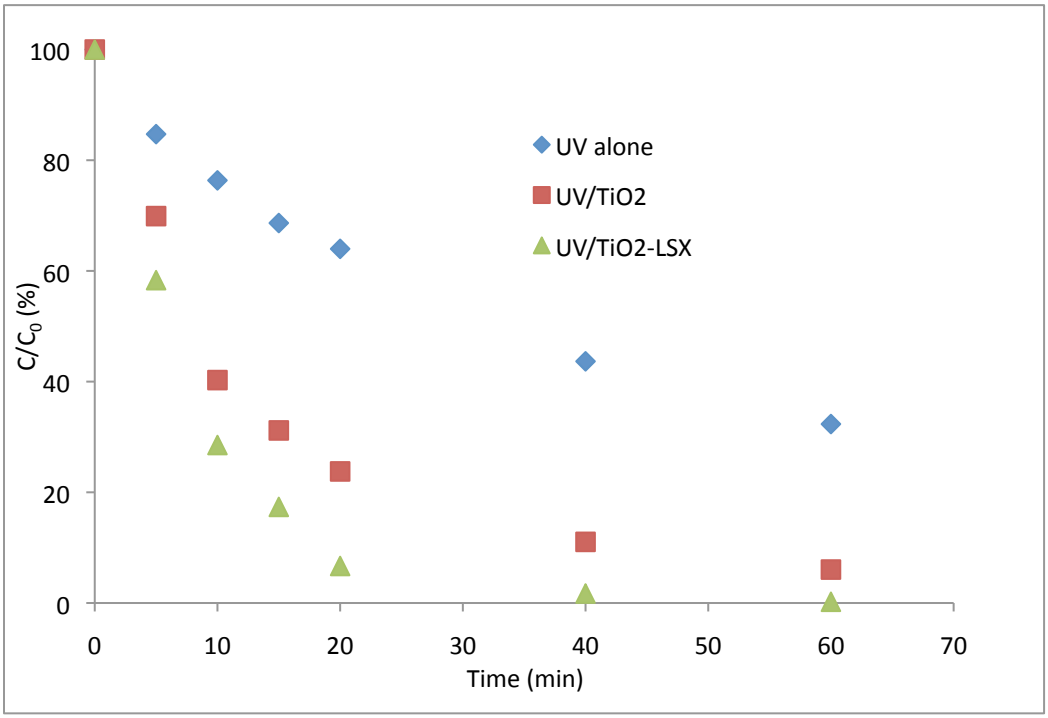

Figure 1. EE2 removal efficiency under UV alone, UV/TiO_2 and UV/TiO_2-LSX ($[EE2]_0$=10 ppm, I_0=1.2576×10^{-5} einstein/min, catalyst concentration is 0.5 g/L)

4. Future work

We have collected LC/MS spectra and are in the process of analyzing them for the possible degradation byproducts. We are also in the process of conducting molecular calculations using Gaussian 09 program. These calculations take a relatively long time to complete (in the order of weeks) and their successful completion will allow us to determine the exact mechanisms by which the TiO_2-doped zeolite enhances photodegradation of EE2.

In the second year, we will a) optimize the dosage of TiO_2 on zeolite, b) use this technology to study the photodegradation of several other PPCPs, c) study the effect of background dissolved organic matter on EE2 photodegradation, and d) spike wastewater from a local WWTP with EE2 and study the efficacy of our technology with respect to its photodegradation.

Do coastal Maine lakes have fish higher in mercury? A targeted survey including lakes in Acadia National Park

Basic Information

Title:	Do coastal Maine lakes have fish higher in mercury? A targeted survey including lakes in Acadia National Park
Project Number:	2012ME270B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	ME-2
Research Category:	Water Quality
Focus Category:	Hydrogeochemistry, Non Point Pollution, Toxic Substances
Descriptors:	None
Principal Investigators:	Sarah Nelson, Aria Amirbahman, Linda Bacon, Stephen A. Norton

Publications

There are no publications.

WRRI Grant Program
Interim Report 5/6/2013

Project Title: Do coastal Maine lakes have fish higher in mercury? A targeted survey including lakes in Acadia National Park

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Co-PIs:

Aria Amirbahman (Civil and Environmental Engineering, University of Maine)

Stephen A. Norton (Earth Sciences, University of Maine)

Student Investigator:

Linda C. Bacon (Lake Assessment Section, ME Dept of Environmental Protection and PhD student, University of Maine)

Cooperators:

David Manski (Acadia National Park)

Gregory Burr (Maine Department of Inland Fisheries & Wildlife)

Project rationale:

Mercury (Hg) is a global contaminant of major concern to both human and wildlife health due to its neurotoxicity. Increased loading of Hg from non-point sources was documented in the continental U.S. in the early 1990s (Swain et. al., 1992), and current Hg loading was recently estimated to be three times pre-industrial deposition (Lindberg *et al.* 2007). In Maine, it is generally accepted that most Hg contained in atmospheric deposition can be traced to anthropogenic emissions from regional, local, and global sources. Increased Hg loading translates to Hg contamination in fish in freshwater and coastal environments (Boesch et. al., 2001). US EPA recently found that approximately half (47%) of the freshwater fish sampled from 76,559 lakes across the US had Hg concentrations that exceeded the EPA's recommended safety level of 300 ppb (US EPA 2009). In the US, all 50 states and all the eastern Canadian provinces have established consumption advisories for marine and/or freshwater fish (EPA, 2008; Environment Canada Website). These advisories affect 43% of the Nation's total lake acreage.

Relevance to Maine and the region:

In Maine, fish tissue Hg concentrations documented in the early 1990s (DiFranco *et al.*, 1995), including notably high concentrations within Acadia National Park (Burgess, 1997) on Mount Desert Island (MDI), resulted in a restrictive, blanket freshwater fish consumption advisory for all Maine lakes and ponds in 1994 and all freshwaters in 1997. This advisory reduces recreational opportunity and eliminates a source of high quality protein for Maine residents. High Hg concentrations also pose a threat to wildlife, including fish-eating birds and mammals; Acadia National Park and other sites in coastal Maine have had Hg values that exceed safety guidelines in bald eagles, tree swallows, and loons, among other species (Evers *et al.* 2005; Longcore *et al.* 2007; Kahl *et al.* 2007). Although the source

of the Hg in Maine is largely atmospheric deposition, Hg concentrations in biota are not uniform in lakes across Maine and are difficult to predict. Rather, Hg contamination of biota is highly variable and it is common for a lake containing fish with high Hg concentration to be located adjacent to another lake with relatively low fish Hg levels.

The existing literature attributed the amount of Hg that ends up in fish partly to the soil, wetlands, and vegetation in the watershed of a water body, the waterbody's specific chemistry, and habitat/behavioral preferences of the species of interest. Fish tissue data collected from Maine lakes over the past 2 decades suggest that there may be elevated Hg concentrations in fish taken from lakes located near coastal areas as compared to inland lakes. *However, to our knowledge, no published studies have focused on the importance of coastal proximity, thus we decided to examine this more closely.*

This project intended to determine whether fish in coastal lakes are particularly sensitive to Hg accumulation. Specifically, we investigated lakes and ponds in Acadia National Park and on MDI where high concentrations of Hg have been found in some fish (Bank et al. 2007), birds (Longcore *et al.* 2007), and amphibians (Bank et al. 2005). This project is part of University of Maine PhD student Linda Bacon's research, who is developing a model for Hg in fish that could help to identify some of the factors that make certain watersheds more likely to have higher fish Hg levels than others.

Project progress:

This project identified 14 lakes within 30 km of the Maine coast on MDI for sampling during field season 2012 (Figure 1). During the spring/summer of 2012, fish tissue samples were collected for analysis of total Hg from 13 of these lakes. Epilimnetic lake water was analyzed for Hg, MeHg, total P, base cations, inorganic anions, DOC, ANC, pH, and chlorophyll from all fourteen lakes. In addition, short sediment cores were collected and will be analyzed for Hg, Fe, Al, and P over the next few months. We are currently analyzing data using a number of approaches including coastal/non-coastal group comparisons, regression analysis (Hg concentration versus distance from coast), and multivariate techniques to look at coastal distance along with P and all the other variables. Preliminary results were presented at the 2013 Maine Water Conference (Bacon *et al.* 2013). Results are being analyzed as part of Bacon's PhD dissertation, which will include a manuscript that will be submitted for publication in a peer-reviewed journal. In addition, this project is being considered for listing in an Acadia National Park Hg synthesis paper (proposed in Nelson *et al.* 2011).

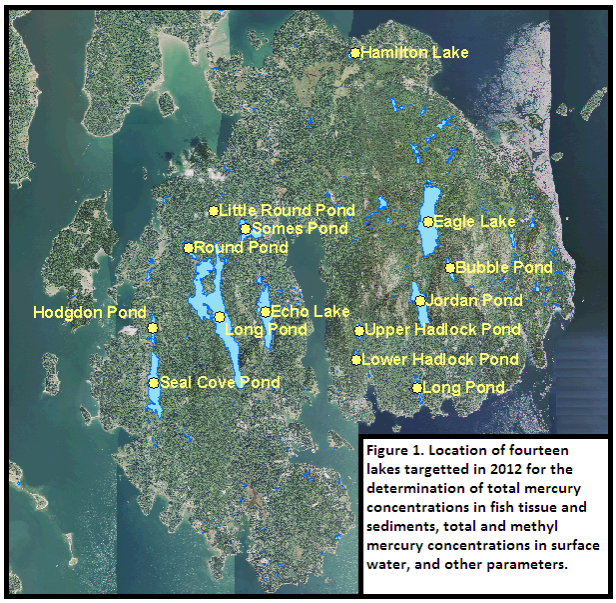

Figure 1. Location of fourteen lakes targetted in 2012 for the determination of total mercury concentrations in fish tissue and sediments, total and methyl mercury concentrations in surface water, and other parameters.

The proposed **objectives** of this project and ***accomplishments***, to date, follow:

- Determine total Hg levels in fish tissue, and total Hg and MeHg concentrations in lake water and sediments in 9 to 15 lakes located within approximately 30 km of the Maine coast;
    - *We have completed this objective, sampling 14 lakes during 2012.*
- Determine the improvement in model predictions when a coastal proximity component is added to models for Hg contamination in fish tissue;
    - *This objective is partly completed and will be part of Bacon's PhD dissertation.*
- Identify relationships between fish Hg concentrations in MDI lakes and Hg concentrations determined in adjacent upland areas;
    - *Preliminary data exploration indicates a slight difference in fish Hg concentrations that has yet to be statistically evaluated.*
- Share results of the project and final Maine model with Maine Center for Disease Control (CDC) toxicologists to use at their discretion.
    - *Implementation of this objective will occur after data analysis is complete and a predictive model for fish Hg bioaccumulation is developed.*

Project Deliverables

Results of this project will be used to determine whether model predictions for fish tissue Hg contamination in Maine are improved with inclusion of a coastal proximity component. Data will be shared with Maine CDC to use at their discretion in the crafting of refinements to the current fish consumption advisory. Deliverables indicated in the proposal will, for the most part, follow data analysis and publication preparation. Preliminary results of the project were presented at the 2013 Maine Water Conference (Bacon et al. 2013).

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Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry

Basic Information

Title:	Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry
Project Number:	2012ME276B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	second Maine
Research Category:	Not Applicable
Focus Category:	Climatological Processes, Hydrogeochemistry, Acid Deposition
Descriptors:	None
Principal Investigators:	Jasmine Saros, Sean David Birkel, Sarah Nelson, Kristin Ditzler Strock

Publications

1. Strock, K.E., S.J. Nelson, J.E. Saros, A. Baumann, J.S. Kahl, W. McDowell. Trends in biogeochemical recovery from acidification in the Northeastern U.S.: new insights from three decades of lake monitoring. Environmental Science and Technology. In prep.
2. Strock, K.E.D., J.E. Saros, S. Nelson. The effects of extreme climate events on lakewater chemistry: Implications for brownification in Maine lakes. Maine Water Conference. Augusta, Maine. March 2013.
3. Strock, K.E.D., J.E. Saros, S.J. Nelson, S.D. Birkel. The effects of extreme climate events on lakewater chemistry: implications for dissolved organic carbon trends in the northeast U.S. American Society of Limnology and Oceanography Meeting. New Orleans, Louisiana. February 2013.
4. Strock, K.E.D., J.E. Saros, S. Nelson. Analyzing legacy data in a climate context to decipher modern changes in lakewater chemistry. BIOGEOMON. Northport, Maine. July 2012.

Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry

Project Number: 2012ME276B
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Project Activities

This project combines existing data, newly developed landscape data, downscaled climate models, and multivariate and time-series statistical techniques to quantify the effects of extreme events on acid-relevant surface water chemistry. The project documents the nature, timing, and frequency of extreme climatic events for over 400 lakes across New England and New York by coordinating data analysis of lake and streamwater data from US EPA long-term research and monitoring projects. This analysis consists of biogeochemical measurements taken over the past three decades by multiple agencies including the USGS, National Park Service, Adirondack Lakes Survey Corporation, and cooperating universities across the Northeast. Data from this project have been used to evaluate trends in surface water acidification and evidence for recovery in acid-sensitive regions in the northeastern US in response to the Clean Air Act Amendments. This project integrates extreme weather data and watershed and hydrogeomorphic characteristics for each lake into a legacy database that includes over 3,000 biogeochemical measurements. Multivariate statistical analyses and routines optimized for time series, landscape analysis, and trend detection are being used to characterize the biogeochemical response of different lake types to extreme weather events. The results provide a framework for evaluating this response for resource managers, and a set of extreme event responses for different lake types that can be used to model the effects of future changes in extreme events. Further, the responses in different lake types can be used to refine expectations of 'recovery' from acidification, and re-define site selection and statistical techniques currently used in assessment of trends in response to atmospheric sulfur reduction. Finally, understanding the links among extreme climate events, reduced sulfur deposition, and watershed characteristics will aid drinking water utilities in assessing the degree of risk and required treatment strength with dissolved organic carbon fluctuations in their water source during extreme weather years.

In the past year, Dr. Birkel worked with an undergraduate student to develop the code necessary to gather weather data from existing climate reanalysis products at a 4 km spatial resolution. Using this code, we've compiled monthly temperature and precipitation data for all of the lakes in the EPA database from 1980 to 2010. Kristin Strock and Dr. Nelson, working in tandem with the US EPA, generated landscape data for each individual watershed to be included in the analysis. This information included watershed elevation and slope, lake area, the area of wetlands in the watershed, and national land cover data that provided the area of forested,

developed, and cultivated land-use types in the watershed. This information is being shared with EPA collaborators who are contributing soils data from the Natural Resource Conservation Service that will include data pertaining to soil depth, porosity, pH, and texture for each watershed.

Project Findings

The landscape and weather data were combined with the existing surface water geochemistry database. Initial statistical analyses included descriptive multivariate approaches which were used to identify the relative contribution of proposed drivers (watershed influences/climate) on lake water chemistry. A principal component analysis was used to identify groups of lakes that respond similarly under different climate scenarios and characterize regional responses in surface water chemistry to extreme drought and extreme wet years. These component axis scores were then related to watershed characteristics to identify potential lake and catchment types that may be particularly sensitive to extreme weather years. It is clear through preliminary exploration of these data that lake chemistry responses to extreme climate events are nonlinear and vary across lakes. For example, sulfate increased across a subset of remote Maine lakes in 2001, suggesting episodic acidification during drought years. This response appears to be more pronounced in catchments with greater wetland coverage. During wet years, there was an increase in dissolved organic carbon (DOC), or episodic brownification. A peak in sulfate has been observed at other individual research sites following a period of drought; however, the extent to which this is characteristic of a broad-scale regional response is still unclear. Our findings not only suggest a statewide chemical response to drought conditions, but also increased brownification in Maine lakes during wet years. Increased DOC concentration, or "brownification," is a phenomenon that has been observed in many regions of the Northern Hemisphere. DOC is a highly diverse pool of organic compounds that impart a brown stain to lake water. These changes have been attributed to both declining sulfur deposition and climate-mediated drivers. DOC is a pivotal regulator of aquatic ecosystems, and increased concentrations can complicate drinking water treatment. Clarifying the response of DOC to extreme weather events across gradients of landscape position and atmospheric deposition is increasingly important for policy and management decisions, as the frequency of extreme rain events continues to increase in this region. This statistical analysis is ongoing and will be completed by June 2013.

Project Deliverables

This project provided support for an undergraduate student for the summer of 2012 and tuition and a stipend for a graduate student for the 2012 – 2013 academic year. A key deliverable of this project is the Ph.D. dissertation of K. Strock that will be completed in the fall of 2013. As part of this dissertation, a manuscript is currently in preparation to be submitted to *Environmental Science and Technology* containing initial statistical analyses of data in the geochemical database to describe trends in recovery from atmospheric deposition across the northeastern U.S. (listed below). This manuscript also discusses the possible implications of extreme weather years on these trends.

This information was also the topic of multiple presentations by K. Strock both as a poster at the most recent BIOGEOMON meeting held in Northport, Maine in July of 2012, and as a talk at the American Society of Limnology and Oceanography meeting in New Orleans, Louisiana in February of 2013. K. Strock also presented the preliminary results of the principal

component analysis (described above) as a talk at the Maine Water Conference in March of 2013 and will also present at the Climate Change Institute's annual Harold W. Borns Jr. Symposium in April of 2013. The results from this analysis will be the subject of a second manuscript and dissertation chapter to be prepared by K. Strock.

Publication:

Strock, K.E., S.J. Nelson, J.E. Saros, A. Baumann, J.S. Kahl, W. McDowell. Trends in biogeochemical recovery from acidification in the Northeastern U.S.: new insights from three decades of lake monitoring. *Environmental Science and Technology*. In prep.

Oral Presentations:

Strock, K.E.D., J.E. Saros, S. Nelson. The effects of extreme climate events on lakewater chemistry: Implications for "brownification" in Maine lakes. Maine Water Conference. Augusta, Maine. March 2013.

Strock, K.E.D., J.E. Saros, S.J. Nelson, S.D. Birkel. The effects of extreme climate events on lakewater chemistry: implications for dissolved organic carbon trends in the northeast U.S. American Society of Limnology and Oceanography Meeting. New Orleans, Louisiana. February 2013.

Poster Presentation:

Strock, K.E.D., J.E. Saros, S. Nelson. Analyzing legacy data in a climate context to decipher modern changes in lakewater chemistry. BIOGEOMON. Northport, Maine. July 2012.

Information Transfer Program Introduction

Information Transfer activities for the Maine Institute can be assigned to five categories: (1) Maine Water Conference; (2) Web-based information; (3) Participation on state-wide boards and committees; (4) Educational Outreach (GET WET!); and (5) Direct response to inquiries. One special project was funded in FY12 to study how municipalities use environmental information to manage salt use for winter road maintenance.

The Maine Water Conference is the primary water event in the state and brings together a broad array of interest groups. This conference is very popular and continues to be the most important information transfer event for the Maine Institute.

The Maine Institute's web page is the location to find information for current issues, activities, and publications. The web page is updated on a regular basis to include project outputs such as publications and presentations. Also, it serves as a notice board for meetings, events, student opportunities, and requests for proposals and calls for abstracts.

The Water Institute Director serves on several state-wide and national boards and committees (e.g. Maine Water Utilities Association, Penobscot River and Bay Institute, American Water Works Association, National Institutes for Water Research). These activities provide opportunities to promote relevant institute-sponsored research and education. Also, it provides a process for the Maine Institute to collect information about the concerns and challenges of water resources in the state and region. This effort helps to keep the Maine Institute at the core of water resources in the state.

Finally, the Water Institute receives public inquiries on a regular basis. Typically, someone is hoping that outcomes from funded projects can help solve their water-related problem. Responding to these inquiries is important and we make every effort to help citizens in finding answers and solutions to their problems. Although most inquiries come from Maine, we have received requests from around the globe.

Maine Salt Management Scoping Project

Basic Information

Title:	Maine Salt Management Scoping Project
Project Number:	2012ME272B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	2
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, Water Quality
Descriptors:	None
Principal Investigators:	Laura Lindenfeld, Karen K Hutchins

Publications

There are no publications.

Maine Salt Management Taskforce Scoping Project: Summary Report

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Prepared for: Maine Salt Management Taskforce

April 2013

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EXECUTIVE SUMMARY

This report summarizes key findings from the WRRI Maine Salt Management Taskforce Scoping Project, January, 2012 – April, 2013. The objectives of the scoping project were to:

1. Review and summarize the scholarly literature on the environmental impacts of salt, existing preventative, structural, and behavioral best management practices and legal ramifications associated with deicing practices;
2. Provide information about and facilitate stakeholders' exploration of at least three different types of BMPs (preventative, structural, and behavioral) that, if found to be successful models, could be adopted by both ME DEP and municipalities;
3. Analyze, identify, and document in a technical report information from stakeholders, including barriers to and opportunities for adopting specific BMPs, stakeholder information needs for altering practices, and current salt management information and management networks in Maine; and
4. Develop an initial proposal for a pilot project to test salt BMPs and a monitoring plan that are cost-effective and acceptable to ME DEP in at least three Maine municipalities.

The first three objectives were met, and between May 2013 and August 2013 a subgroup of the taskforce will be drafting BMPs for potential adoption statewide. Starting summer 2013, we are also initiating a pilot project that uses network analysis methods to study BMP adoption and the factors that influence such adoption. We felt it was critical to first improve our understanding of current practices and adoption rates of new practices prior to determining which BMPs need piloting and monitoring.

Key Findings:

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INTRODUCTION

This technical report summarizes the findings from the 2012-2013 Maine Salt Management Scoping Project, conducted by the University of Maine in collaboration with the Maine Salt Management Taskforce. This research was funded by the United States Geological Survey through the Water Resources Resource Institute at the University of Maine and Maine's Sustainability Solutions Initiative (SSI) (see Appendix B for a summary of SSI and its research goals), Maine EPSCoR, and the National Science Foundation.

The objectives of the scoping project were to:

1. Review and summarize the scholarly literature on the environmental impacts of salt, existing preventative, structural, and behavioral best management practices and legal ramifications associated with deicing practices;
2. Provide information about and facilitate stakeholders' exploration of at least three different types of BMPs (preventative, structural, and behavioral) that, if found to be successful models, could be adopted by both ME DEP and municipalities;
3. Analyze, identify, and document in a technical report information from stakeholders, including barriers to and opportunities for adopting specific BMPs, stakeholder information needs for altering practices, and current salt management information and management networks in Maine; and
4. Develop an initial proposal for a pilot project to test salt BMPs and a monitoring plan that are cost-effective and acceptable to ME DEP in at least three Maine municipalities.

This report has two primary sections. In the first section, we review the findings from our literature review of the economic, environmental, and social impacts of road salt and review of local and national existing salt management practices. In the second section, we review the findings from our study of the barriers and opportunities for adopting specific BMPs, stakeholder information needs, and current road maintenance information and communication networks in Maine.

Through this study we: a) provide up-to-date, scientific data on the impacts of road salt, b) synthesize information on the best management practices being used in Maine and around the country for the management of road salt in winter road maintenance, c) identify key resources in the state for BMP training, testing, and promotion, d) discover initial data on the barriers to and opportunities for altering current management practices to reduce road salt use, and e) suggest areas for additional research, opportunities for improved communication, and potential BMPs for piloting.

STUDY ADMINISTRATION AND METHODS

Literature Review: Environmental, Social, and Economic Impacts

The literature review conducted for the pilot study builds from the extensive literature review conducted as part of the 2010 report, "Maine Winter Roads: Salt, Safety, Environment and Cost," by the Margaret Chase Smith Policy Center at the University of Maine (see the 2010 report for addition literature review data: www.umaine.edu/files/2010/02/Winter-Road-Maint-Final.pdf*)*. Based on the literature reviewed in the 2010 report, we analyzed the peer-reviewed literature from 2009 to 2012. To conduct this review, we used the following academic databases: *ProQuest, Environmental Science Collection, EBSCO, Communication and Mass Media Complete, Wildlife and Ecology Studies Worldwide, Environment Complete, Academic Search Complete, Science*

Direct, Ecology Abstracts, Pollution Abstracts, Web of Knowledge, Web of Science, Nature, and Maine Environmental Monitoring and Assessment Program Index (MEMAP). In addition, we searched *Google Scholar* and reviewed the reference pages of acquired articles to verify that we had exhausted our search. Search terms included, *Road Salt, Road Salt and Effects, Road Salt and Best Management Practices, Chloride and Effects, Chloride and Effects and Roads, Chloride and Best Management Practices, Sodium and Effects, Sodium and Best Management Practices, Deicing, Deicing and Effects, and Deicing and Best Management Practices.* In our reading of the articles, we identified hypotheses, study methods and measures, results, and authors' recommended best management practices or additional research, if provided in the article. We then summarized briefly how this information related to the scoping project questions.

The findings from the literature review are summarized in the section titled "Study Findings," section A. The reference list includes only those articles cited in the summary; it is not an exhaustive list of all articles reviewed.

Review: Winter Road Maintenance and Road Salt Best Management Practices

While our literature review was global, our review of best management practices was focused on practices in Maine and North America. We narrowed our focus because of feedback from the Taskforce that they would like to first see what works locally. We found conducting this part of the review challenging because many of the practices occurring within, for example, a municipality are not documented online. Thus, we compiled a list of cold-climate states (California, Colorado, Connecticut, Idaho, Iowa, Maine, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New York, North Carolina, North Dakota, Oregon, South Dakota, Utah, Washington, Wisconsin, and Vermont) and searched each state's Department of Transportation and Department of Environmental Protection websites. In some states, we contacted them via e-mail to access additional resources. We also searched organizations known for studying road salt and winter road maintenance issues (e.g. *Clear Roads, the Salt Institute*). Further, we researched *Environment Canada*, a government agency tasked with protecting Canada's natural environment. *Environment Canada* has relatively strict chloride regulations.

Based on the data, we created a list of five best management practice categories, including salt application and technologies, salt storage and handling, equipment maintenance, training and certification, and behavior change programs. The summaries of these best management practices and what they are intended to address are listed in the section titled, "Study Findings," section B.

Facilitated Workshops

We hosted three facilitated workshops as part of the scoping project. We held the initial face-to-face workshop in April 2012 at the Maine DEP in Augusta. We established the following goals for the workshop:

- Based on our literature review, provide information on the social, economic, and ecological effects of road salt.
- Identify additional information needs about the impact of road salt in Maine.
- Identify the group's critical concerns about road salt management, including the effects of road salt.
    - Promote mutual learning and identify areas of commonality and conflict among meeting participants through small and large group exercises.

We achieved these goals through research presentations, brief hand-outs, and facilitated small and large group discussions. In response to the low turnout at the April meeting and participant requests, we held the second and third workshops via videoconference at four Maine DEP locations: Portland, Augusta, Bangor, and Presque Isle. We established the following goals for the second workshop:

- Based on research findings, present information on three categories of best management practices being implemented in the United States.
- Discuss research findings and identify currently implemented winter road maintenance and road salt BMPs in Maine (e.g. what are we already doing? What do people perceive as current salt BMPs?).
- Solicit from the group ideas about what policies and practices might best address their key concerns, and which type of BMPs they would like to explore further at the meeting. These ideas will help narrow our BMP research for the July meeting and ensure that the BMPs presented align with concerns of participants.

Based on discussion in the second workshop, we chose to hold focus groups and individual interviews after the second meeting in order to identify currently-implemented local and state BMPs. The focus group data was needed prior to continuing discussions as a group.

We held the third workshop via videoconference at four Maine DEP locations: Portland, Augusta, Bangor, and Presque Isle. We established the following goals for the workshop:

- Updates on group activities since second facilitated workshop
- Summary of research findings, focusing on focus group, trainings, and individual interview findings
- Discuss research findings as a group and receive feedback
- Review salt management taskforce matrix from September 2010 salt management roundtable
- Planning next steps for the taskforce

Focus Groups and Interviews

Feedback generated during the facilitated workshops revealed a gap in our data. The general consensus was that we needed additional information about management practices in Maine. As previously noted, many of the management practices used at the local level are not accessible online. Thus, we determined that we needed to talk directly with municipal officials to get this information. We chose to conduct focus groups because they are an efficient way to gather data about a specific issue or to identify trends and patterns in attitudes, experiences, and knowledge[1]. Focus groups also provide an opportunity for participants to meet and learn from each other, and they also help researchers weed out extreme views, since "participants tend to provide checks and balances on each other[2]" (p. 386). We held two focus groups, one in Portland and one in Orono. Unfortunately, despite e-mails to 21 municipal officials, primarily in public works departments, participation in the focus groups was low. We had two participants in Portland and two participants in Orono. With that said, the data gathered during these focus groups was invaluable. We gained insight on local best management practices, winter road maintenance information resources, barriers to and opportunities for BMP adoption, and research and management interests and concerns. We plan to hold a third focus group in Presque Isle this summer and conduct individual interviews throughout Maine.

We also interviewed two individuals from a quasi-governmental state agency and met with four individuals from Maine Local Roads.

---

[1] Kitzinger, J., & Barbour, R. S. (1999). Introduction: the challenge and promise of focus groups. *Developing focus group research: Politics, theory and practice*, 1-20.
[2] Patton, M. (2002). *Qualitative Research and Evaluation Methods*. CA: SAGE.

Participant Observation

Participant observation involves observing group interactions and documenting conversation themes/ideas. We have taken advantage of numerous opportunities for participant observation during the scoping project including observations at one statewide roundtable all-day meeting and three Salt Management Taskforce meetings prior to starting the project. During the project, we conducted participant observations at three facilitated workshop meetings, two focus groups, and at one Maine Local Roads training, "Economics of Snow and Ice Control" in Caribou, Maine. Notes were taken during these events, and researchers recorded observations and reflections after the events.

Data Analysis

We compiled an annotated bibliography for the literature review to document hypotheses, methods, results, and research implications for each article. We assembled a list of best management practices from state DOT and DEP websites and organizations studying road salt and road salt management. From this list, we identified differences and similarities in practices by state and broke the data into major categories of practices.

We recorded and transcribed two workshops, focus group, and one interview. We took detailed notes at the third workshop, training, and interview with Maine Local Roads. From those transcripts and notes, we analyzed the data using a deductive coding approach. We established a set of coding themes to align with the best management categories and information sources we previously identified and added to that list when new themes, such as sharing equipment and social capital, emerged. After our initial round of coding, we analyzed the codes to identify broad themes in the data[3].

Our participant observations and formal discussions led us to initiate a new research project through which we will explore how an innovation, like a best management practice or new equipment, is adopted in different areas of the state, identifying factors that might promote adoption, such as Maine Local Roads trainings, or hinder it, such as being an isolated community. Our hope is that this information will help the Taskforce identify methods for disseminating future findings and information about future initiatives and improve our understanding of factors that influence BMP adoption generally.

STUDY LIMITATIONS

As with any study, there are limitations to the data collected. First, the individuals involved in the taskforce meetings and focus groups are not representative of municipalities in Maine. The majority of participants are from regulated MS4 communities with strict stormwater requirements. These typically are larger, urban or suburban areas. In addition, despite some outreach efforts, we have yet to involve participants from western or downeast Maine. Second, the municipal agents involved in the facilitated meetings and focus groups are employees of establish public works departments. Yet, as we discovered during this study, the majority of municipalities in Maine use private contractors to maintain their roads in winter. Our findings are limited because of the disparity between participants and the population of municipal-level winter road maintenance professionals. With that said, this study helped us uncover this critical piece of information, and future studies will benefit from recruiting participation by municipal contractors.

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[3] Glesne, C. (2006). *Becoming Qualitative Researchers: An Introduction* (3rd ed.) New York: Longman.

STUDY FINDINGS

A. Literature Review

a. Environmental, economic, and social impacts of road salt

Environmental Impacts

Key Concepts

1. Salt is naturally occurring and comes in different forms, including sodium chloride (NaCl), magnesium chloride ($MgCl_2$), and calcium chloride ($CaCl_2$).

2. Road salts (primarily NaCl in the studies examined for this review) enter water bodies through four primary ways: surface flows (runoff), ground water inputs, aerosols, and long-term leaching (from soil) (Kincaid & Findlay, 2009; Rubin et al., 2010).

3. "Determination of critical levels of sodium or chloride perhaps should not only include considerations of lethal levels, but also effects on biodiversity and ecosystem function . . ." (Kelly et al., 2008, p. 414).

Surface and Groundwater

Streams and Groundwater:

1. **Road salt significantly contributes to chloride imports into surface and ground water (Trowbridge et al., 2010).**
   a) Chloride concentrations in streams will vary with the time of year, frequency, and type of precipitation events (Rubin et al., 2010), stream flow (inverse relationship), and watershed size (Trowbridge et al., 2010).

2. **Studies document a positive relationship between road density in a watershed and chloride concentrations in streams (Rhodes, Newton & Pufall, 2001).**
   a) In Maine, initial research documents that chloride levels increase with increases in the extent of impervious cover (presentation, Parr, 2011). Additional research is needed to fully explore this relationship, including road type and buffer, as demonstrated by Kelting et al. (2012)

3. **One of the concerns with chloride is that it appears to be retained in the system long after initial runoff (Kincaid & Findlay, 2009).**
   a) Studies document that high levels of chloride occur periodically throughout the year, not only with inputs from storm-event runoff or during snowmelt.
      i. Surface waters with high chloride concentrations during summer months suggest that chloride is entering through groundwater (Kelly et al., 2008) or long-term leaching (Kincaid & Findlay, 2009). According to prior research, up to 50% of the salt ends up in groundwater. Depending on soil type, salty solutions can be detected for several hundred meters away from a treated road (Rubin et al., 2010).

   b) Studies show that rather than moving readily through soils, chloride may be retained in soils for an extended period of time:

i. Kincaid and Findlay (2009) suggest that, if chloride is retained in the soils, rain events in spring and summer may influence the passage of chloride from the soils into the groundwater, in certain soil types.

Lakes and Groundwater:

1. **A strong, positive correlation exists between chloride and sodium levels and total paved road density by *road type* (interstate highways, state, local) and by *road proximity* to the shoreline (Kelting et al., 2012).**

    a) Kelting et al. (2012) found that, in Adirondack Park in New York, the density of paved state roads explained 84% of the variation in sodium and chloride levels in 82 lakes in the watershed. Similarly, when buffer width (distance of roads from the lake) was added to the model with density of paved state roads, it allowed the researchers to explain 87% of variation in sodium and chloride levels in the lakes.

    b) Although local roads (county, municipal, private) significantly contributed to changes in chloride concentrations in the lakes, local roads explained less than 1% of the variation in chloride, indicating they did not help explain much of the changes in chloride concentrations.

2. **In locations where sodium chloride is applied for deicing, chloride concentrations of urban lakes have increased to levels that can change natural lake-mixing behavior and influence aquatic life (Novotny & Stefan, 2010).**

    a) Sodium chloride inputs can alter lake-mixing by adding a denser saline water layer above the lakebed in winter and spring. The impact can be extended hypoxia (no/low oxygen) in bottom waters during spring and summer, with the potential for increased phosphate release or heavy metal release from lake sediments (Novotny & Stefan, 2010).

3. **Researchers are concerned that elevated chloride concentration in lakes can cause damage to aquatic life, largely through increases in chloride in the lake sediment** (Bridgeman et al., 2000, as cited in Novotny & Stefan, 2010).
    a) According to Lakes Environmental Association in Western Maine (2011), "Maine's lakes bring $2.3 billion dollars annually into Maine's economy" (par. 4). This annual contribution includes visitor spending and resident income and employment.

4. **Studies show that previously contaminated, chloride-enriched groundwater continues to seep into lakes, even after salt application load is reduced (Toran et al., 2010).**
    a) Toran et al. (2010) demonstrate that groundwater contaminated by road salt is an important source of chloride input into Mirror Lake in New Hampshire. Despite decreased road salt inputs into the environment, chloride-enriched groundwater continues to contribute to elevated levels of chloride in the lake.

Soil

1. **Road salt can mobilize heavy metals in soils (Nelson et al., 2009) and decrease heavy metal (copper, zinc, cadmium, and nickel) retention in stormwater treatment systems (Tromp et al., 2012).**
    a) Introduction of sodium chloride to loam and sandy loam soils showed increases in heavy metal mobilization, including lead, copper, and cadmium; there was a smaller release of lead in the loam than sandy loam soils (Nelson et al., 2009).

2. **Road salt impacts soil chemistry, structural composition of soil (Findlay & Kelly, 2011), and dissolved organic carbon (DOC) levels (Green et al., 2009).**
    a) The introduction of sodium chloride can impact soil chemistry. Sodium may displace other ions, like potassium[4], from negatively charged sites releasing them back into the system and potentially into the ground or surface water (Findlay & Kelly, 2011).
        i. Changes in soil chemistry may impact the organisms that depend on those elements.

3. **Impacts of road salt (sodium chloride specifically) vary with soil chemistry (Nelson et al., 2009) and type (Olofsson & Lundmark, 2009), prior soil exposure to sodium chloride (Green et al., 2009), and the bioavailability of the released compounds (Nelson et al., 2009).**
    a) Heavy metal releases are dependent on the levels of heavy metals already existing in the soils, and larger releases are likely in soils with lower pH (Green et al., 2009).
    b) Chloride retention (Kincaid & Findlay, 2009) and the distance chloride travels in the soils vary with soil types (Olofsson & Lundmark, 2009).

Freshwater Species

1. **High levels of chloride (above 1300 mg/L) may be toxic to freshwater mussels (Gillis, 2011), the most endangered group of animals in North America (ME Inland Fisheries & Wildlife, 2010., par. 7).**
    a) Natural habitat features, like hard water and natural buffers, may decrease the effect of chloride in natural habitats (Gillis, 2011).

Amphibians

1. **Many amphibians breed in agricultural or stormwater ponds, which become reservoirs of road-deicing agents when located along or near roads. In New England, researchers found road salt contamination in vernal pools up to 172 meters from the highway (Karraker et al, 2008).**

2. **Amphibians exposed to high concentrations of sodium chloride experience significant physiological changes, such as slower developmental rates (Karraker et al., 2008) and slower movements that may decrease the likelihood of escaping predators (Denoel et al., 2010).**

    a) During specific spring conditions, high chloride levels reduce the amount of water intake into spotted salamander (A. *maculatum*) embryos, increasing the risks of freezing and development malformations.

3. **Amphibians that reside closer to roads are more vulnerable because high road salt concentrations are most prevalent in roadside vernal pools, with concentrations decreasing exponentially with increasing distance from the road (Karraker et al., 2008).**

    a) Massachusetts established a 1700 mile, salt reduction use area in order to protect important ecological elements, such as vernal pools and the amphibians that depend on those pools (Karraker et al., 2008).

Vegetation

1. **High levels of sodium chloride negatively impact almost all the processes taking place in plants. Road salt disturbs the ionic balance in plants, and this effect is considered the main reason for declining road-side tree health (Dmuchowski et al., 2011).**

[4] Potassium (K^+) is critical for plant growth. If potassium is washed out of the system because it is released by sodium, an important part of the ecosystem is lost. Retrieved from: http://www.enviroliteracy.org/article.php/1019.html.

2. **Invasive plant species tend to persist in salt contaminated areas where salt-intolerant vegetation has declined (Rubin et al., 2010).**

Economic Impacts

Economic Impacts of Road Salt

Draft 4.25.12

Authors: Maine Salt Management Scoping Project Team

Infrastructure

1. **Chloride-based deicers have been shown to harm concrete infrastructure (Shi et al., 2009).**

   a) Reactions with cement paste and/or aggregates reduce concrete integrity and strength, which in turn may allow moisture, oxygen, and other agents to enter the concrete and interact with the rebar surface to cause rebar corrosion (Shi et al., 2009).

2. **Chloride ions from road salt may cause corrosion from pitting and severely damage stainless steel structures (Asaduzzaman et al., 2011).**

   a) All of the common chlorides used in deicing corrode metals through atmospheric deposition (Rubin et al., 2010).

3. **One study estimated salt-related damages nationally at $5.5 million. The estimate included corrosion damage to bridges, highways and vehicles. (Hayes et al., 1996 as cited in Meegoda et al., 2004).**

Equipment

1. **In comparison to other regions in the United States, the Northeast experiences extremely high automobile corrosion rates, primarily due to atmospheric corrosion (exposure to pollutants in the air) stemming from deicing salts (Tullmin & Roberge, 2000).**

   a) Rubin et al. (2010) found that atmospheric corrosion primarily harms the electrical and brake systems of vehicles.

2. **Sodium chloride causes vehicle corrosion, resulting in potentially significant repair expenses for families, schools, commercial businesses, and governments (Rubin et al., 2010).**

3. **There are potentially significant costs associated with properly washing public works and safety vehicles to protect the fleet from corrosion, while also minimizing environmental impacts from washing.**

   a) Truck washing after a major storm is encouraged to protect the trucks and associated equipment from corrosion (Meegoda et al., 2004). Maintaining facilities to wash this equipment requires regular inspection of washing areas for wash pads, sediments, sump, and oils separators.

Salt Storage

1. **Salt storage facilities are critical for reducing large-scale point-source pollution from road salt. Costs of these facilities range, depending on amount of material, quality of storage facility, and infrastructural needs for loading salt.**

   a) Best management practices for salt storage facilities include, but are not limited to, roofed storage facilities, enclosed conveyors, and strategically placed stockpiles (Meegoda et al, 2004)

Material Costs

The Margaret Chase Smith Policy Center (MCSPC) report by Rubin et al. (2010) provides a comprehensive overview of the costs of winter road maintenance in Maine, including material costs. Some of these costs are highlighted below.

1. **According to the MCSPC report, on average, Maine municipalities spent almost 70 million dollars on winter road maintenance in 2008-2009 and used 55% of the total salt statewide.**
   a) Maine DOT spent almost 30 million and used approximately 19% of total salt statewide.
   b) The Maine Turnpike Authority (MTA) spent less than 5 million and used approximately 3% of the total salt statewide.

Accidents

1. **The average cost of accidents in Maine over a 10 year period (1999-2009) was $1.5 billion dollars (Rubin et al., 2010, p. 58).**
   a) The average cost of accidents in Maine was determined using Maine's accident data and the US Department of Transportation guidelines on cost per each type of accident.

2. **Total accident costs are declining in Maine due to fewer year-round accidents on Maine roadways.**
   a) According to Rubin et al. (2010), "The total number of accidents has fallen 26% over the decade or at a simple annual decline of 2.6%" (p. 59). Reasons for accident decline may include improved vehicle design, demographic changes, fewer impaired drivers, and improved roads and winter maintenance practices.
   b) Between 2000 and 2008, Maine highways experienced 27 fewer winter-month fatalities than predicted based on regression analyses of Maine crash data (Rubin et al., 2010). Approximating total costs per death at $3.51 million, preventing 27 deaths saved approximately $94 million (Rubin et al., 2010, p. 66).

Commerce

1. **According to a study funded by the Salt Institute (2011), blizzards that shut down roadways may cost between $62 and almost $600 million per day, depending on the state.**

2. **Further research is needed to quantify the economic benefits of clear roads for the trucking and business industries.**
   a) A primary concern of the transportation industry is mobility. They need major roads to be clear in order to transport goods (Rubin et al., 2010).

Remediation

1. **According to a 2004 report in the *Maine Townsman*, well water contamination claims may cost municipalities thousands of dollars in assessment costs. If contamination is discovered, remediation may cost tens of thousands of dollars (Taylor et al., 2004, par. 2).**

Social Impacts

Social and Public Safety Impacts of Road Salt

Draft 4.25.12

Authors: Maine Salt Management Scoping Project Team

Groundwater Contamination

1. **In accordance with US EPA drinking water standards, concentrations of sodium in drinking water should not exceed 20 mg/L, and chloride levels should not exceed 250 mg/L (Rubin et al., 2010).**
    a) Limits on sodium levels are related to health concerns because of the association of dietary sodium and hypertension (Rubin et al., 2010); sodium levels in drinking water are of particular concern for people on low-sodium diets (MassDOT, 2012). Limits on chloride levels are related to taste and potential corrosion of infrastructure (MassDOT, 2012).

Accidents

1. **Research indicates that as road conditions deteriorate (e.g. icy roads) accident frequency increases (Usman et al., 2010). Factors such as traffic volume, visibility, and precipitation must also be considered.**

2. **Over the last decade, there was a significant reduction in fatalities on Maine highways during the winter months (Rubin et al., 2010).**

3. **Research demonstrates that salt piles on/near roadways attract animals, such as moose and deer, thus increasing the likelihood of animal collisions with motor vehicles.**
    a) Reducing the number of salt piles next to roadways will decrease the frequency with which animals, specifically moose, cross the road. Decreased road crossings should decrease collisions (Grosman et al., 2011).[5]

Mobility

1. **Due to improved maintenance, and thus fewer road conditions of snow and ice, people can travel more during winter months in Maine (Rubin et al., 2010).**

2. **Further research is needed to determine the level of service required for the safe mobility of public safety vehicles.**
    a) Concerns about clearing roads for public safety vehicles were raised by stakeholders involved in Margaret Chase Smith Policy Center focus groups and by members of the Maine Salt Management Taskforce. This literature review did not produce research that specifically addressed concerns about public safety vehicle mobility.

[5] According to a 2009 press release by the Maine Department of Transportation, there have been over 600 moose-related vehicle crashes since 1999; 22 resulted in fatalities. According to Rubin et al. (2010) (based on US Department of Transportation data), each fatality costs approximately $3.6 million. Based on that approximation, 22 fatalities are estimated to cost over $79 million dollars.

B. Road Salt Best Management Practices (BMPs)

a. BMPs in Maine

The following results are generated from two focus groups with two municipal agents per focus group; two interviews with quasi-governmental state agents and affiliated state groups, with three and four participants, respectively; group discussions at three facilitated meetings, and participation in a *Maine Local Roads* training program, "Economics of Snow and Ice Control." Additional Maine-implemented BMPs that we discovered through online sources are referenced in the next section titled "BMPs Nationally and Internationally." We recognize that the following list is not exhaustive and that additional focus groups and interviews are needed to determine the variety of practices used in different areas of the state. In addition, a survey of municipalities might be helpful for determining a precise count of how many municipalities, and which types, use which BMPs to manage snow and ice. With that said, practices were largely consistent across focus groups, interviews, and facilitated meetings, although practices did vary by municipality size and location.
As expected, larger municipalities tend to use newer technology and techniques than smaller municipalities, likely because of economic resources and need. While reading this section, it is critical to keep in mind that all of the municipal officials involved in the focus groups and facilitated meetings work for established public works departments, and are from urban or suburban communities.

Maine Department of Transportation and Maine Turnpike Authority are leaders in the state in relation to winter road maintenance, using the latest technology and techniques.

Salt and Sand Storage and Use: The majority of participants indicated that they stored their salt inside permanent structures on an impervious surface. One municipality reported storing their liquid deicers indoors; two reported storing sand indoors, and one indicated they store their sand outside under a tarp on bare ground.

The majority indicated they mix their sand with salt to prevent freezing; one indicated the municipality does not use much sand/salt mix, and one indicated using almost entirely salt. Four municipalities reported using liquid magnesium chloride in their treatment practices, with one municipality indicating he previously tried calcium chloride and Ice-B-Gone before switching to magnesium chloride.

Interestingly, one municipality and a quasi-governmental agency indicated that acquiring material and receiving bids for materials begins in early summer. Three municipalities indicated they touched based with one or more surrounding community to split liquid deicer loads. Municipalities reported going to local MDOT facilities to get salt and liquid deicers.

At a Maine Local Roads training in Caribou, Maine, the speaker recommended using salt only in a mix with sand on gravel roads.

One official emphasized the importance of establishing priority road guidelines for each municipality, whereby material use varies depending, partially, on prioritization. Another official discussed the importance of being aware of aquifers and other critical water sources when considering what material to use, how, and where.

One quasi-governmental state agency reported using sand only when absolutely necessary and actively trying to use as little salt as possible. Other comments made about materials: "salt gets too much of a bad rap" and two people indicated that they thought sand was more of a problem than salt environmentally.

Calibration: All municipalities and quasi-governmental and affiliated state agents interviewed discussed calibrating equipment. Two municipalities and all state agents reported that their systems were computerized. Two mentioned setting the "size of the door opening," and the importance of spending time to calibrate equipment. Although drivers can disperse more material than originally allocated, the equipment is calibrated by supervisors prior to the trucks being dispersed. Prior to distributing additional material, drivers typically check with supervisors.

Equipment: Equipment type varied by municipality and government level (i.e. state or local). One municipality reported that all of their trucks had GPS units. While no municipalities reported using road weather information systems (RWIS), the quasi-governmental state agency reported using two RWIS systems at specific locations. Four municipalities indicated using local weather channels, pavement monitoring, and ambient temperatures to determine storm patterns and to inform their understanding of road conditions.

One municipality reported using a belly pan for the main roads, but no special blades, while another municipality reported not using a belly pan, nor using any special blades. One municipality reported using carbide blades, and one discussed the importance of using a centerline hopper spreader. The quasi-governmental state agency reported that all of their main plows have underbelly scrapers. Two state and quasi-governmental state agencies are experimenting with carbide blades and finger blades. Carbide blades are reported to be more cost-effective than steel blades because they last longer. Consistent with the Maine Local Roads training, an official reported, "the blade is the number one thing for getting rid of snow and ice."

One municipality reported using a snow blower to clean sidewalks.

Common in our discussions with agents is the expense associated with switching equipment. Much of the equipment lasts for 25 or more years and upgrading and changing that equipment is costly. While all officials indicated being open to piloting new equipment and techniques, they can only do so if it is economical.

Treatment:

Prewetting: three municipalities reported prewetting their salt or sand/salt loads as the material is being released from the truck. There is a liquid storage tank on trucks that have prewetting capacity. A quasi-governmental state agency stated that they have their material, road salt and water, mixed before the storm. Maine Local Roads trainers recommend spraying sand material on dirt roads as well. Prewetting is encouraged because it helps ensure that the salt and/or sand remains on the roadway, instead of bouncing off, and it provides a moisture source that helps activate the salt. In addition, materials such as magnesium chloride and calcium chloride may be sprayed onto the salt to help it work at lower temperatures, as these materials work better than sodium chloride at low temperatures. One municipal official reported, "prewetting is the cheapest and most cost saving method, while using less sand." Finally, one quasi-governmental state agent reported using magnesium chloride, depending on cost and availability, to improve the effectiveness of salt at low temperatures.

Pre-treating: Only one municipality reported pre-treating roads, an anti-icing practice that prevents snow and ice from bonding with the road. This municipal official indicated that they "prewet" about two hours before the storm in certain places. One municipality that did not pre-treat stated that "we're just not set up to do it." Two state and quasi-governmental state agencies reported pre-treating roads prior to the storm event. The quasi-governmental state agency reported using salt brine as the pre-treatment agent.

During our conversations, there did seem to be some confusion over terms. Prewetting and pretreating were used somewhat interchangeably. This could partially have been the researchers' fault, as we may have erroneously been using the terms interchangeably during conversations as well.

Training Process: Training varied by municipality. Two municipalities indicated sending all operators to Maine Local Roads' and Maine DOT trainings, while another indicated sending supervisors only. Three municipalities mentioned what excellent resources Phil and Pete are from Maine Local Roads, as well as Brian Burne from Maine DOT. Vendors also provide training on new equipment.

Officials emphasized the importance of in-house training, particularly placing new drivers with more experienced drives. Yet, three municipal officials discussed the challenges associated with getting experienced employees to change practices when new techniques and technologies are available. The comment was made that it is easier to train the new guys who do not have the background and history in the field. With that said, experience with storms, road conditions, and routes is clearly in important part of winter road maintenance.

One quasi-governmental state agency reported having an annual salt management training for all employees, and new employees are trained as they are hired.

One municipal official mentioned that he has a very detailed training manual that is critical for educating his staff and training new drivers.

Alternatives/New Techniques: When asked if they were open to piloting equipment, the majority reported that they were always open to trying new things and would be willing to pilot equipment, if the costs were right.

When presented with the question, "if money wasn't an object, what type of equipment, material, or practices would you implement for managing road salt?" One official indicated he would probably use more salt if it was less expensive. Two municipal and quasi-governmental state agents expressed interest in Ice-B-Gone or beet juice, but expressed concerns with costs and economies of scale. Both identified that materials made of agricultural products, such as beet juice, are more environmentally friendly. In contrast, one person doubted the benefits of switching to alternative materials, stating, "a different material just causes other impacts." Finally, one person expressed interest in trying rubberized carbide blades, and one quasi-governmental state agent expressed interest in trying different pre-treatment/anti-icing liquid material and perhaps moving to all liquid for all conditions.

Decision-Making: When asked who made the decisions regarding calibration, three reported that supervisors or foremen pre-set the equipment for particular application rates and that, while the drivers can "boost" their supply when needed, the drivers typically call into their supervisors to request the "boost" and consult on application rates. One person stated, "supervisors have to make decision on how to attack these storms." Changing materials (i.e. changing from salt to sand or to hot sand) happens at the supervisory level as well.

b. BMPs Nationally and Internationally

Road Salt Application and Technologies: Research by the taskforce revealed Iowa and Michigan as leaders in effective development and use of road salt application technologies. Both states are known for their availability of information to the public, usage of new technologies, and staff education. Michigan uses new technologies

including: Automated Anti-Icing Spray System, SafeLane Surface Overly System, Road Weather Information Systems (RWIS), and global positioning satellite systems, and state-of-the-art ground speed control systems[6]. The Iowa DOT employs a similar RWIS network, including 62 sites throughout the state. In addition, the state has integrated precipitation sensors called weather identifier and visibility sensors (WIVIS) that interpret the rate, type, and visibility distance of occurring precipitation[7].

Behavior Change Programs: The behavioral programs examined by the taskforce in the United States and Canada commonly employ social marketing techniques and media campaigns to encourage safer driving practices in winter and improved salt application techniques. In 2007, the Wisconsin Department of Transportation in collaboration with the Clear Roads organization produced the "Ice and Snow...Take it Slow" campaign. This program targeted high risk drivers throughout the United States via television and web advertisements[8]. The Halifax Regional Municipality follows a similar educational model. They offer a comprehensive set of public education and communication programs including councilor education and publicly available information regarding snow maintenance and operations[9].

Salt Storage and Handling & Truck Maintenance: Advanced storage facilities and effective and efficient maintenance practices are central to the best practices regarding salt storage and handling and truck maintenance. Research shows the Maine DOT has begun to move, when possible, liquid storage tanks inside in order to contain unexpected spills onto non-impervious surfaces[10]. Further, the Maine DEP requires that new construction of storage areas and Priority 4 and 5 storage areas[11] to be located on at least a three inch pad of asphalt[12]. With respect to the Maine DEP, they currently require new salt storage areas to be located 300 feet or further from a well. This is excluding any well that serves the storage area, and they cannot overlie significant sand and gravel aquifer or a source water protection area[13]. In addition, to distance, soils and shape should be considered when siting sand or salt piles in order to minimize direct runoff from facility to stream.

Research has found other states, particularly Massachusetts and Michigan, have similar regulations to Maine in terms of salt storage and handling. Massachusetts restricts storage of uncovered salt piles in areas that threaten water supplies (Mass. General Law Ch. 85, section 7A) and enforce drinking water regulations that restrict deicing chemical storage within wellhead protection areas (310 CMR 22.21(2)(b)). Michigan also has

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[6] Emerging Technologies in Winter Road Maintenance - Improving Safety While Minimizing Environmental Impacts. Michigan Department of Transportation. Retrieved from: www.michigan.gov/documents/stormwatermgt/MDOT_MS4_Emerging_Technologies_in_Winter_Road_Maintenance_208451_7.pdf

[7] Iowa's Winter Maintenance Technologies Research. Iowa Department of Transportation. Retrieved from: www.iowadot.gov/research/pdf/Research News August 2009.pdf

[8] http://www.clearroads.org/downloads/09-21winterdrivingmessages-final-report.pdf

[9] http://www.halifax.ca/snow/

[10] Personal Communication with Brian Burne, Maine DOT, 7.13.12.

[11] Maine DEP in collaboration with Maine DOT developed a sand/salt pile priority list for municipal and county sand/salt storage areas. The list, approved in 2000, assists DOT will allocating reimbursement funds for the construction of sand/salt storage facilities.

[12] Chapter 574, Siting and Operation of Road Salt and Sand-Salt Storage Areas, Maine Department of Environmental Protection. Retrieved from: www.maine.gov/dep/water/wd/sandsalt/#intro.

[13] Chapter 574, Siting and Operation of Road Salt and Sand-Salt Storage Areas, Maine Department of Environmental Protection. Retrieved from: www.maine.gov/dep/water/wd/sandsalt/#intro.

legislation that requires impervious asphalt or coated concrete floors in storage facilities to minimize salt contaminants from seeping into groundwater.

Training and Certification Programs: Training and certification programs are a recent development in management practices in the United States. Popularized in Canada, these programs regularly include educating local municipalities and private applicators. Such programs commonly encompass training on topics concerning calibration methods, material choice, application methods, and proper snow disposal. The mark of effective programs between the United States and Canada are decrease in the amount of material used and overall material expenses during the winter season. Programs throughout the United States and Canada typically are voluntary and occur annually, often in partnerships with Departments of Transportation or Environmental Protection, engineering firms, or universities.

Leading programs are offered by the Minnesota Pollution Control Agency (MPCA) and New Hampshire's Technology Transfer Center. The MPCA's Road Salt Education Program, initiated in 2005, targets government and private applicators. This program educates participants on the do's and don'ts of deicing and calibration methods. Following the training, participants are given a voluntary exam over the topics covered. Upon successful completion of the exam participants are awarded a Level 1 Training Certificate[14].

Research finds that the implementation of training and certification programs can have significant economic benefits. The Minnesota Pollution Control Agency Road Salt Education Program, City of Toronto, and Otterburn Park [15] have all cited significant cost and material savings. The City of Toronto claims saving $1,820,500 and 36,410 tons of material between the 2001 to 2002 winter season[16]. The training program offered by Fortin Consulting, as used by the MPCA, was found to have saved Dakota County 4,500 tons of salt between the winter seasons of 2008 and 2009[1].

C. Manager Concerns with Potential Statewide Management in Maine

The Maine Salt Management Taskforce, as a group, expressed interest in thinking about if standards for road salt best management practices could be developed for a statewide audience. Concerns were raised about the recommendations only targeting municipalities with urban impaired streams, without addressing salt management as a statewide issue. In light of these concerns, in the interviews and focus groups we asked the following questions: "What do you see as the opportunities and or problems with suggesting statewide BMPs?" and "What, if any, regional differences do you think should be considered when developing statewide BMPs for road salt?"

In general, participants seemed supportive of best management practices, but they were extremely hesitant about regulations on road salt, especially given limited budgets. One participant expressed concerns with regulations because of issues with public safety, enforcement of regulations, and the complexity of winter road maintenance. In light of this complexity, all participants noted that one size does not fit all when it comes to

[14] MPCA Road Salt Education Program. Minnesota Pollution Control Agency. Retrieved from: www.pca.state.mn.us/index.php/about-mpca/mpca-events-and-training/road-salt-education-program.html?menuid=&redirect=1.

[15] Case Study # 5: Salt Reductions through a New Approach to Winter Maintenance Practices - Otterburn Park, Quebec. Environment Canada. Retrieved from: www.ec.gc.ca/nopp/roadsalt/cStudies/pdfs/5%20-%20Otterburn%20Park%20-%2004%2005%2003.pdf.

[16] Case Study #4: City of Toronto – Salt Use Reductions through Employee Training. Environment Canada. Retrieved from: www.ec.gc.ca/nopp/roadsalt/cStudies/pdfs/4%20-%20City%20of%20Toronto%20-%2004%2003%2026.pdf.

winter road maintenance. The following variables were identified: 1) there are very real regional differences, particularly in weather patterns and weather variation by region. For example, one participant discussed the constant drifting issues in Aroostook County because of large quantities of open fields and stated that their temperatures, on average, are much colder than the rest of the state, which requires applying more salt than in warmer climates. Another participant noted the differences in precipitation in the mountain versus coastal regions. 2) There are also storm-by-storm differences. Each storm behaves slightly differently and, thus, snow and ice control approaches need to be adaptable to changes in conditions. 3) There are different categories of roads with different priority levels, demanding different levels of treatment. 4) Regional expectations influence winter maintenance practices. 5) Finally, BMPs need to vary by municipality size. Larger communities have different capacities than smaller communities. One participant noted, "let small towns do their own thing." Participants appreciated that small towns may not have the fiscal or human capacity to make significant changes to their operations. While the majority of participants seemed willing to entertain the idea of statewide BMPs, they stated that any BMPs suggested would need to be flexible enough to accommodate the inherent variations in winter road maintenance, such as those identified above.

Reported benefits of developing statewide practices include 1) regional coordination and potentially regional equipment and material sharing, and 2) improved regional collaboration between small and large communities. Participants offered several suggestions for regionalizing practices. Three individuals supported the idea of developing a template BMP manual for snow and ice control that could be filled in with municipality-specific information and adapted to local conditions. Another individual suggested that all municipalities should establish a priority road system. In relation to recommendations for improving winter maintenance, one agent discussed the importance of having a salt management plan and a training program in place.

Several times we heard that, in order to alter our practices, we need to educate the traveling public. Over and over again, public safety was mentioned as a central factor in winter road maintenance decision making. One person stated, "my staff's job and the town's job is to make sure the roads are safe to travel on," while another person said that he checks with public safety personnel after a storm and asks how the accidents were the night before. If he hears that it was a good night, he feels like he has done his job well. The lives of citizens and public safety vehicle access to citizens in need weigh heavily on the minds of public works officials. Any changes to policies need to recognize this deep dedication to citizen safety. With that said, they are also responsive to "phone calls" from the public. Choices are often influenced by public complaints.

The Public: Comments about the public were often in reference to their safety or their complaints about driving conditions. In addition, one community reported that the public accepted his municipality's switch to a salt priority community, while another person indicated that the public would likely be supportive of piloting changes in practices because Maine has "an environmentally conscious public." Another official thought the public's environmental consciousness would only go so far because they still wanted clear roads.

D. Resource Networks and Communication: Maine Municipalities and State Agencies

Information Sources: As discussed in the section on BMPs in Maine, Maine Local Roads and the Maine Chapter of the American Public Works Association (APWA) are critical resources for training public works professionals in Maine. One quasi-governmental state agent also highlighted the International Bridge, Tunnel, and Turnpike Association (IBTTA) as an important resource for information and a good place for networking. While contractors participate in trainings with these organizations on a limited basis, they do not seem to participate at the same level as personnel from public works departments. With that said, contractors were not

involved in the focus groups, interviews, or facilitated meetings, so it is unclear primary sources of their winter road maintenance training.

When asked about key sources for information about winter maintenance practices, participants identified Maine Local Roads, Maine DOT and Maine DOT's Snow College, fellow municipalities, APWA, vendors, Highway Congress, National Snow and Ice Expo, Salt Institute (online), and the Federal Highway Association. Magazines, such as *Roads and Bridges*, *Better Roads*, and *Public Works Magazine*, were also identified.

Finally, discussions revealed that learning about techniques often occurs by experimenting. People test out what works and then may try a different technique.

Sharing: Municipalities, State Agencies: Results reveal that sharing resources and knowledge between municipalities, between municipalities and the MDOT, and between state and quasi-governmental state agencies is a critical part of the culture and social learning process associated with winter road maintenance. Types of resources shared include: parts, materials, equipment, and liquid material (because it is delivered in large quantities and requires particular types of storage). Knowledge of what works and what does not work is central to the learning and training process for winter road maintenance professionals. While officials did note that larger municipalities often assist smaller municipalities, they also noted that sharing is influenced by proximity and size, if the municipality employees a contractor or has an established public works department, and personalities.

FUTURE RESEARCH

Future research will focus on discovering how an innovation, like a best management practice or new equipment, is adopted throughout the state, identifying factors that might promote adoption (like Maine Local Roads trainings), or hinder it (like being an isolated community). Given the large number of municipalities who utilize private contractors to maintain their roads in winter, future studies must involve contractors in order to ascertain their specific practices, training resources, communication networks, and unique barriers to and opportunities for improved salt (and sand) management.

CONCLUSION

The information gathered in this survey is essential for understanding the scientifically documented environmental, social, and economic impacts of road salt, the current best management practices being implemented in Maine and around the country, opportunities for improving implementation, and needs for future research. This pilot project served as an initial step for the Taskforce in their work to answer questions asked during the Salt Management Roundtable in 2010, to fill-in data and knowledge gaps, and explore the future of road salt management and regulations. This project has helped strengthen collaborations between municipalities throughout Maine, between various stakeholder groups and regulatory agencies like Maine DEP, and between the University of Maine and participants of the Maine Salt Management Taskforce. In addition, this project is leading to new research that will serve the Taskforce and assist the State of Maine in becoming a leader in collaborative road salt management practices.

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APPENDIX A – Maine's Sustainability Solutions Initiative

The Maine Sustainability Solutions Initiative (SSI) is a team of over 35 faculty members from universities and colleges throughout Maine. The SSI is currently funded by the National Science Foundation (NSF) EPSCoR program, a five-year $20 million grant that will help the University of Maine System build an infrastructure for the study of sustainability science. One of the SSI's overarching goals is to systematically examine its collective research processes and contribute to a growing body of literature on the process of linking knowledge with action (K↔A). The SSI's research design includes repetitive cycles among field research, collaborative assessment, evaluation, communication, and reflexivity. This ongoing learning spiral, based on action and observation, feedback, and co-evolutionary development, will refine a replicable, place-based protocol for sustainability science that builds model research strategies and institutional innovations[17] within a structure of collaborative stakeholder-university partnerships.

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APPENDIX B – Workshop Handouts
Environmental Impacts of Road Salt

Draft 4.25.12

Authors: Maine Salt Management Scoping Project Team

Key Concepts

4. Salt is naturally occurring and comes in different forms, including sodium chloride (NaCl), magnesium chloride ($MgCl_2$), and calcium chloride ($CaCl_2$).

5. Road salts (primarily NaCl in the studies examined for this review) enter water bodies through four primary ways: surface flows (runoff), ground water inputs, aerosols, and long-term leaching (from soil) (Kincaid & Findlay, 2009; Rubin et al., 2010).

6. "Determination of critical levels of sodium or chloride perhaps should not only include considerations of lethal levels, but also effects on biodiversity and ecosystem function . . ." (Kelly et al., 2008, p. 414).

Surface and Groundwater
Streams and Groundwater:

4. **Road salt significantly contributes to chloride imports into surface and ground water (Trowbridge et al., 2010).**
    b) Chloride concentrations in streams will vary with the time of year, frequency, and type of precipitation events (Rubin et al., 2010), stream flow (inverse relationship), and watershed size (Trowbridge et al., 2010).

5. **Studies document a positive relationship between road density in a watershed and chloride concentrations in streams (Rhodes, Newton & Pufall, 2001).**
    b) In Maine, initial research documents that chloride levels increase with increases in the extent of impervious cover (presentation, Parr, 2011). Additional research is needed to fully explore this relationship, including road type and buffer, as demonstrated by Kelting et al. (2012)

6. **One of the concerns with chloride is that it appears to be retained in the system long after initial runoff (Kincaid & Findlay, 2009).**
    c) Studies document that high levels of chloride occur periodically throughout the year, not only with inputs from storm-event runoff or during snowmelt.
        i. Surface waters with high chloride concentrations during summer months suggest that chloride is entering through groundwater (Kelly et al., 2008) or long-term leaching (Kincaid & Findlay, 2009). According to prior research, up to 50% of the salt ends up in groundwater. Depending on soil type, salty solutions can be detected for several hundred meters away from a treated road (Rubin et al., 2010).

d) Studies show that rather than moving readily through soils, chloride may be retained in soils for an extended period of time:

i. Kincaid and Findlay (2009) suggest that, if chloride is retained in the soils, rain events in spring and summer may influence the passage of chloride from the soils into the groundwater, in certain soil types.

Lakes and Groundwater:

5. **A strong, positive correlation exists between chloride and sodium levels and total paved road density by *road type* (interstate highways, state, local) and by *road proximity* to the shoreline (Kelting et al., 2012).**

   c) Kelting et al. (2012) found that, in Adirondack Park in New York, the density of paved state roads explained 84% of the variation in sodium and chloride levels in 82 lakes in the watershed. Similarly, when buffer width (distance of roads from the lake) was added to the model with density of paved state roads, it allowed the researchers to explain 87% of variation in sodium and chloride levels in the lakes.

   d) Although local roads (county, municipal, private) significantly contributed to changes in chloride concentrations in the lakes, local roads explained less than 1% of the variation in chloride, indicating they did not help explain much of the changes in chloride concentrations.

6. **In locations where sodium chloride is applied for deicing, chloride concentrations of urban lakes have increased to levels that can change natural lake-mixing behavior and influence aquatic life (Novotny & Stefan, 2010).**

   b) Sodium chloride inputs can alter lake-mixing by adding a denser saline water layer above the lakebed in winter and spring. The impact can be extended hypoxia (no/low oxygen) in bottom waters during spring and summer, with the potential for increased phosphate release or heavy metal release from lake sediments (Novotny & Stefan, 2010).

7. **Researchers are concerned that elevated chloride concentration in lakes can cause damage to aquatic life, largely through increases in chloride in the lake sediment** (Bridgeman et al., 2000, as cited in Novotny & Stefan, 2010).

   b) According to Lakes Environmental Association in Western Maine (2011), "Maine's lakes bring $2.3 billion dollars annually into Maine's economy" (par. 4). This annual contribution includes visitor spending and resident income and employment.

8. **Studies show that previously contaminated, chloride-enriched groundwater continues to seep into lakes, even after salt application load is reduced (Toran et al., 2010).**

   a) Toran et al. (2010) demonstrate that groundwater contaminated by road salt is an important source of chloride input into Mirror Lake in New Hampshire. Despite decreased road salt inputs into the environment, chloride-enriched groundwater continues to contribute to elevated levels of chloride in the lake.

Soil

4. **Road salt can mobilize heavy metals in soils (Nelson et al., 2009) and decrease heavy metal (copper, zinc, cadmium, and nickel) retention in stormwater treatment systems (Tromp et al., 2012).**

   b) Introduction of sodium chloride to loam and sandy loam soils showed increases in heavy metal mobilization, including lead, copper, and cadmium; there was a smaller release of lead in the loam than sandy loam soils (Nelson et al., 2009).

5. **Road salt impacts soil chemistry, structural composition of soil (Findlay & Kelly, 2011), and dissolved organic carbon (DOC) levels (Green et al., 2009).**
    b) The introduction of sodium chloride can impact soil chemistry. Sodium may displace other ions, like potassium[18], from negatively charged sites releasing them back into the system and potentially into the ground or surface water (Findlay & Kelly, 2011).
        ii. Changes in soil chemistry may impact the organisms that depend on those elements.

6. **Impacts of road salt (sodium chloride specifically) vary with soil chemistry (Nelson et al., 2009) and type (Olofsson & Lundmark, 2009), prior soil exposure to sodium chloride (Green et al., 2009), and the bioavailability of the released compounds (Nelson et al., 2009).**
    c) Heavy metal releases are dependent on the levels of heavy metals already existing in the soils, and larger releases are likely in soils with lower pH (Green et al., 2009).
    d) Chloride retention (Kincaid & Findlay, 2009) and the distance chloride travels in the soils vary with soil types (Olofsson & Lundmark, 2009).

Freshwater Species

2. **High levels of chloride (above 1300 mg/L) may be toxic to freshwater mussels (Gillis, 2011), the most endangered group of animals in North America (ME Inland Fisheries & Wildlife, 2010., par. 7).**
    b) Natural habitat features, like hard water and natural buffers, may decrease the effect of chloride in natural habitats (Gillis, 2011).

Amphibians

4. **Many amphibians breed in agricultural or stormwater ponds, which become reservoirs of road-deicing agents when located along or near roads. In New England, researchers found road salt contamination in vernal pools up to 172 meters from the highway (Karraker et al, 2008).**

5. **Amphibians exposed to high concentrations of sodium chloride experience significant physiological changes, such as slower developmental rates (Karraker et al., 2008) and slower movements that may decrease the likelihood of escaping predators (Denoel et al., 2010).**

    b) During specific spring conditions, high chloride levels reduce the amount of water intake into spotted salamander (A. *maculatum*) embryos, increasing the risks of freezing and development malformations.

6. **Amphibians that reside closer to roads are more vulnerable because high road salt concentrations are most prevalent in roadside vernal pools, with concentrations decreasing exponentially with increasing distance from the road (Karraker et al., 2008).**

    b) Massachusetts established a 1700 mile, salt reduction use area in order to protect important ecological elements, such as vernal pools and the amphibians that depend on those pools (Karraker et al., 2008).

Vegetation

2. **High levels of sodium chloride negatively impact almost all the processes taking place in plants. Road salt disturbs the ionic balance in plants, and this effect is considered the main reason for declining road-side tree health (Dmuchowski et al., 2011).**

[18] Potassium (K^+) is critical for plant growth. If potassium is washed out of the system because it is released by sodium, an important part of the ecosystem is lost. Retrieved from: http://www.enviroliteracy.org/article.php/1019.html.

2. **Invasive plant species tend to persist in salt contaminated areas where salt-intolerant vegetation has declined (Rubin et al., 2010).**

Economic Impacts of Road Salt

Draft 4.25.12

Authors: Maine Salt Management Scoping Project Team

Infrastructure

4. **Chloride-based deicers have been shown to harm concrete infrastructure (Shi et al., 2009).**

   b) Reactions with cement paste and/or aggregates reduce concrete integrity and strength, which in turn may allow moisture, oxygen, and other agents to enter the concrete and interact with the rebar surface to cause rebar corrosion (Shi et al., 2009).

5. **Chloride ions from road salt may cause corrosion from pitting and severely damage stainless steel structures (Asaduzzaman et al., 2011).**

   b) All of the common chlorides used in deicing corrode metals through atmospheric deposition (Rubin et al., 2010).

6. **One study estimated salt-related damages nationally at $5.5 million. The estimate included corrosion damage to bridges, highways and vehicles. (Hayes et al., 1996 as cited in Meegoda et al., 2004).**

Equipment

4. **In comparison to other regions in the United States, the Northeast experiences extremely high automobile corrosion rates, primarily due to atmospheric corrosion (exposure to pollutants in the air) stemming from deicing salts (Tullmin & Roberge, 2000).**

   a) Rubin et al. (2010) found that atmospheric corrosion primarily harms the electrical and brake systems of vehicles.

5. **Sodium chloride causes vehicle corrosion, resulting in potentially significant repair expenses for families, schools, commercial businesses, and governments (Rubin et al., 2010).**

6. **There are potentially significant costs associated with properly washing public works and safety vehicles to protect the fleet from corrosion, while also minimizing environmental impacts from washing.**

   b) Truck washing after a major storm is encouraged to protect the trucks and associated equipment from corrosion (Meegoda et al., 2004). Maintaining facilities to wash this equipment requires regular inspection of washing areas for wash pads, sediments, sump, and oils separators.

Salt Storage

2. **Salt storage facilities are critical for reducing large-scale point-source pollution from road salt. Costs of these facilities range, depending on amount of material, quality of storage facility, and infrastructural needs for loading salt.**

   b) Best management practices for salt storage facilities include, but are not limited to, roofed storage facilities, enclosed conveyors, and strategically placed stockpiles (Meegoda et al, 2004)

Material Costs

The Margaret Chase Smith Policy Center (MCSPC) report by Rubin et al. (2010) provides a comprehensive overview of the costs of winter road maintenance in Maine, including material costs. Some of these costs are highlighted below.

2. **According to the MCSPC report, on average, Maine municipalities spent almost 70 million dollars on winter road maintenance in 2008-2009 and used 55% of the total salt statewide.**
   a) Maine DOT spent almost 30 million and used approximately 19% of total salt statewide.
   b) The Maine Turnpike Authority (MTA) spent less than 5 million and used approximately 3% of the total salt statewide.

Accidents

3. **The average cost of accidents in Maine over a 10 year period (1999-2009) was $1.5 billion dollars (Rubin et al., 2010, p. 58).**
   b) The average cost of accidents in Maine was determined using Maine's accident data and the US Department of Transportation guidelines on cost per each type of accident.

4. **Total accident costs are declining in Maine due to fewer year-round accidents on Maine roadways.**
   c) According to Rubin et al. (2010), "The total number of accidents has fallen 26% over the decade or at a simple annual decline of 2.6%" (p. 59). Reasons for accident decline may include improved vehicle design, demographic changes, fewer impaired drivers, and improved roads and winter maintenance practices.
   d) Between 2000 and 2008, Maine highways experienced 27 fewer winter-month fatalities than predicted based on regression analyses of Maine crash data (Rubin et al., 2010). Approximating total costs per death at $3.51 million, preventing 27 deaths saved approximately $94 million (Rubin et al., 2010, p. 66).

Commerce

3. **According to a study funded by the Salt Institute (2011), blizzards that shut down roadways may cost between $62 and almost $600 million per day, depending on the state.**

4. **Further research is needed to quantify the economic benefits of clear roads for the trucking and business industries.**
   a) A primary concern of the transportation industry is mobility. They need major roads to be clear in order to transport goods (Rubin et al., 2010).

Remediation

2. **According to a 2004 report in the *Maine Townsman*, well water contamination claims may cost municipalities thousands of dollars in assessment costs. If contamination is discovered, remediation may cost tens of thousands of dollars (Taylor et al., 2004, par. 2).**

Groundwater Contamination

2. **In accordance with US EPA drinking water standards, concentrations of sodium in drinking water should not exceed 20 mg/L, and chloride levels should not exceed 250 mg/L (Rubin et al., 2010).**
    b) Limits on sodium levels are related to health concerns because of the association of dietary sodium and hypertension (Rubin et al., 2010); sodium levels in drinking water are of particular concern for people on low-sodium diets (MassDOT, 2012). Limits on chloride levels are related to taste and potential corrosion of infrastructure (MassDOT, 2012).

Accidents

4. **Research indicates that as road conditions deteriorate (e.g. icy roads) accident frequency increases (Usman et al., 2010). Factors such as traffic volume, visibility, and precipitation must also be considered.**

5. **Over the last decade, there was a significant reduction in fatalities on Maine highways during the winter months (Rubin et al., 2010).**

6. **Research demonstrates that salt piles on/near roadways attract animals, such as moose and deer, thus increasing the likelihood of animal collisions with motor vehicles.**
    b) Reducing the number of salt piles next to roadways will decrease the frequency with which animals, specifically moose, cross the road. Decreased road crossings should decrease collisions (Grosman et al., 2011).[19]

Mobility

3. **Due to improved maintenance, and thus fewer road conditions of snow and ice, people can travel more during winter months in Maine (Rubin et al., 2010).**

4. **Further research is needed to determine the level of service required for the safe mobility of public safety vehicles.**
    b) Concerns about clearing roads for public safety vehicles were raised by stakeholders involved in Margaret Chase Smith Policy Center focus groups and by members of the Maine Salt Management Taskforce. This literature review did not produce research that specifically addressed concerns about public safety vehicle mobility.

[19] According to a 2009 press release by the Maine Department of Transportation, there have been over 600 moose-related vehicle crashes since 1999; 22 resulted in fatalities. According to Rubin et al. (2010) (based on US Department of Transportation data), each fatality costs approximately $3.6 million. Based on that approximation, 22 fatalities are estimated to cost over $79 million dollars.

Road Salt Application and Technologies

Best Practices Overview:

Distribution timing, truck efficiency, and access to the latest technology all influence the amount of road salt applied to roads, parking lots, and sidewalks. Improper or excessive application can significantly increase the amount of road salt entering nearby ecosystems, potentially damaging those ecological systems. Throughout the US, numerous states have created and implemented best practices to prevent the excess use of road salt. Key practices range from specific treatment practices, such as anti-icing techniques, to the development of new and/or improved technologies, such as snow plow design.

Treatments:

Weather forecasting is a major factor in proper winter maintenance as it helps winter-road maintenance professionals anticipate and proactively address winter weather conditions[20]. If proper treatments are applied before a storm, small quantities of road salt are generally sufficient. Anti-Icing: Anti-icing involves using a liquid or solid chemical treatment that depresses the freezing-point, creates a brine layer, and prevents snow and ice from bonding with pavement.[21] De-icing: De-icing is intended to help break up a layer of already-bonded snow-pack or ice and may use liquid or solid chemicals and abrasives[22] It can be very effective for melting black ice and freezing rain[23]. While anti-icing may be viewed as a preventative approach and deicing as a reactive approach, in reality, it is likely that one moves back and forth between these practices during storm events and anti-icing techniques may improve the ability to deice rapidly. Pre-wetting: In most states the pre-wetting process involves spraying a solution made up of water and salt onto dry salt as it is applied to roads. Pre-wetted de-icers remain on the surface and less salt is needed later in the storm to break the snow or ice bond with the pavement[24]. Pre-wetting may also involve the application of a straight liquid to the road surfaces. Maine DOT uses a combination of magnesium chloride, salt brine, and Ice B' Gone (www.icebegone.com/)[25] for their pre-wetting treatments.

Technologies:

Salt Application Trucks: Advanced salt truck technology, such as zero velocity spreaders, specialized plow designs, and infrared technology, is central to salt reduction. Zero Velocity Spreader: Materials coming from the back of the truck are calibrated to be dispensed matching the forward speed for a zero velocity impact. This results in less scattered material off of the roadways and makes it easier for operators to place the material exactly where they want it on the roadway. Plow Design (3 blade system): The three blade system involves a squeegee blade to reduce excess moisture, a scraping blade to break up the ice, and a carbide blade for durability. This system provides for more efficient and effective winter road maintenance than achievable with previous blade designs. Improved

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[25] Personal Communication with Brian Burne, Maine DOT, 7.13.12.

maintenance generally results in a reduction of salt use because less salt is needed. Results on the effectiveness of multi-blade systems are documented in a report on clearroads.org[26]. Flexible Carbide Blades: New technology is continuing to be developed for flexible blade designs that mount to a regular snow plow. These flexible systems include a carbide blade set in a flexible system with rubber to reduce shock, wear and tear, vibration, and noise. The small, flexible segments allow the blade to adjust to roadway contours[27], improving the ability to clear the roads. Research from the Iowa Department of Transportation and Maine DOT indicate that these blades, specifically the JOMA Black Cat Blades (www.jomablackcat.com), may last up to three times longer than the standard carbide blades[28]. However, they are significantly more expensive than the standard blades. Ground Speed Control: Trucks in the Michigan DOT fleet have state-of-the-art ground speed control, which allows for a consistent flow of material out of the spreader chute at any speed. When the truck slows down or stops for an intersection, the flight chain simultaneously slows down and stops, helping to eliminate excessive salt spread at low speeds[29]. Maine DOT also uses this technology. Trucks without Ground Speed Control can also stop salt spreading at intersections, but the process is manual and not automated[30].

Roadways: Roadways can also be equipped with advanced technology, such as anti-icing spray systems and road weather information systems, to aid in effective winter road maintenance and the reduction of road salt use. Automated Anti-icing Spray Systems: This system was implemented by the Michigan DOT in 2000 when a highway reconstruction project provided the opportunity to incorporate 175 automated spray nozzles that distribute anti-icing chemicals for improved winter driving safety on the roadway, bridges and ramps. The system starts the automated spraying cycle when manually activated by phone (located at US-131 passing through Grand Rapids). There can be some quirks with these systems because of false alarms resulting in unnecessary spraying and the loss of costly materials. However, some states have reported significant reductions in accident rates in high-risk areas[31]. Road Weather Information Systems (RWIS): RWIS maximize ice removal effectiveness by prioritizing areas in need. The system includes meteorological and pavement sensors, communications and planning tools, and real-time readings, which can help operators decide what treatment to apply during reported conditions[32]. Limitations of the RWIS are the high up-front costs and the risk of cars running into them[33]. Thermal Mapping: This low cost mapping system provides a temperature profile of roadways, which can be utilized for planning treatments during a storm. The system combines the use of infrared thermometers, a GPS antenna and a laptop computer to collect and store data in order to develop a customized de-icer application based on specific roadway surface needs[34]

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[26] Multiple-Blade Snowplow Project Final Report. CTC & Associates, LLC and Clear Roads. Retrieved from: www.clearroads.org/downloads/Multiple-Blade-Snowplow-Project-Final%20Report_1-6-11.pdf.
[27] Iowa's Winter Maintenance Technologies Research. Iowa Department of Transportation. Retrieved from: www.iowadot.gov/research/pdf/Research News August 2009.pdf
[28] Iowa's Winter Maintenance Technologies Research. Iowa Department of Transportation. Retrieved from: www.iowadot.gov/research/pdf/Research News August 2009.pdf and personal communication with Brian Burne, Maine DOT, 7.13.12.
[29] Iowa Stormwater Education Program. Retrieved from: www.iowastormwater.org/index.php?option=com_content&view=article&id=105%3Asalt-a-deicing-workshop-presentations&catid=40&Itemid=78
[30] Maine Salt Management Taskforce discussions, 4.25.12 taskforce meeting.
[31] Personal communication with Brian Burne, Maine DOT, 7.13.12.
[32] Emerging Technologies in Winter Road Maintenance - Improving Safety While Minimizing Environmental Impacts. Michigan Department of Transportation. Retrieved from: www.michigan.gov/documents/stormwatermgt/MDOT_MS4_Emerging_Technologies_in_Winter_Road_Maintenance_208451_7.pdf
[33] Personal communication with Brian Burne, Maine DOT, 7.13.12.
[34] Iowa's Winter Maintenance Technologies Research. Iowa Department of Transportation. Retrieved from: www.iowadot.gov/research/pdf/Research News August 2009.pdf

Issues Addressed by the BMPs

Proactive treatment systems and new technologies help prevent and reduce the potential for contaminating surface water, groundwater, soil, and nearby ecological systems by reducing the amount of salt used and improving targeted and appropriate application rates. The amount of road salt entering the ecological system can be minimized by calibrating trucks and having weather systems determine the appropriate treatment procedure. By implementing these practices, operators can more effectively manage storm events, maintain quality winter driving conditions, and reduce the amount of road salt applied.

Leaders in Salt Application Reduction:

Michigan and Iowa are both leaders in road salt reduction with their advanced technologies and application procedures. These states provide information on treatment practices, improved and emerging technologies, and education about proper application procedures. Listed below are some of the standout practices and technologies:

- Michigan is a leader in improved technologies. Implemented technologies include: Automated Anti-Icing Spray System, SafeLane™ Surface Overlay System (an epoxy-aggregate pavement surface with naturally reactive deicer release), Road Weather Information System (RWIS), Global positioning satellite system, and state-of-the-art ground speed control systems. The state also partners with universities to research and develop optimal and improved application practices[35].
- The Iowa DOT installed its first road weather information system (RWIS) site in 1988. Today, the department maintains 62 RWIS sites throughout the state. They added to the RWIS by adding new precipitation sensors called weather identifier and visibility sensors (WIVIS) that interpret the rate and type of falling precipitation and visibility distance[36].

[35] Emerging Technologies in Winter Road Maintenance - Improving Safety While Minimizing Environmental Impacts. Michigan Department of Transportation. Retrieved from: www.michigan.gov/documents/stormwatermgt/MDOT_MS4_Emerging_Technologies_in_Winter_Road_Maintenance_208451_7.pdf

[36] Iowa's Winter Maintenance Technologies Research. Iowa Department of Transportation. Retrieved from: www.iowadot.gov/research/pdf/Research News August 2009.pdf

Salt Storage and Handling and Truck Maintenance

Best Practices Overview:

Historically, there have been incidents where large amounts of salt runoff from improperly maintained salt storage facilities have contaminated both public and private drinking water supplies and caused significant impacts to the surrounding ecosystems[37]. To minimize this form of contamination, several states throughout the US have developed facilities and adopted practices aimed at reducing salt runoff and groundwater infiltration. Key practices include the development and implementation of advanced storage facilities and efficient and effective maintenance practices.

Storage:

In order to minimize salt runoff and ground water infiltration, key factors to consider when building salt storage facilities include salt-pile and facility coverage, pavement type, facility siting, and salt handling. Coverage: Salt-piles and storage facilities should always be enclosed to prevent runoff. If a town is unable to provide a full enclosure facility, it is best to have at least an impervious storage pad and a waterproof cover.[1] Maine DOT is beginning to move, when possible, their liquid storage tanks inside so that unexpected spills can be contained[38]. Pavement Type: Impervious surfaces such as asphalt or coated concrete are the best options for ground coverage because the impermeability of the material prevents salt contaminates from seeping into the groundwater supply. Maine DEP requires new storage areas and Priority 4 and 5 storage areas[39] to be located on at least a three inch pad of asphalt[40]. Location: Several states have enacted restrictions to guide the placement of salt storage facilities. Specifically, regulations set specific limits on how close the salt piles can be to surface waters and drinking water sources, preventing direct runoff into surface water and drinking water contamination. For example, Michigan requires that all solid salt must be stored a minimum of 50 feet from the banks or shore of any stream or lake[41]. Maine DEP requires that new salt storage areas be located 300 feet or further from a well, excluding any well that serves the storage area, and they cannot overlie a significant sand and gravel aquifer or a source water protection area[42]. In addition to distance, soils and slope should be considered when siting sand/salt piles in order to minimize direct runoff from facility to stream. Where there is a direct threat of runoff entering a stream, retention basins should be considered. Handling: One of the best ways to reduce salt runoff during handling is to have enclosed conveyor belts. Indoor conveyor belts are more cost effective than outside truck loading because less salt is lost during the loading process and the likelihood of salt getting wet from exposure is reduced[43]. Conveyor belts do have a high upfront cost. By developing sound storage facilities and handling practices, salt runoff can be greatly reduced, minimizing impacts to human health and ecosystems.

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[37] Guidelines On Deicing Chemical (Road Salt) Storage. Massachusetts Department of Environmental Protection. Retrieved from: www.mass.gov/dep/water/laws/saltgui.htm.

[38] Personal Communication with Brian Burne, Maine DOT, 7.13.12.

[39] Maine DEP in collaboration with Maine DOT developed a sand/salt pile priority list for municipal and county sand/salt storage areas. The list, approved in 2000, assists DOT will allocating reimbursement funds for the construction of sand/salt storage facilities.

[40] Chapter 574, Siting and Operation of Road Salt and Sand-Salt Storage Areas, Maine Department of Environmental Protection. Retrieved from: www.maine.gov/dep/water/wd/sandsalt/#intro.

[41] Salt and Brine Storage Guidance. Michigan Department of Environmental Quality. Retrieved from: www.michigan.gov/documents/deq/deq-ess-p2tas-bulksaltbrineguidance_267024_7.pdf.

[42] Chapter 574, Siting and Operation of Road Salt and Sand-Salt Storage Areas, Maine Department of Environmental Protection. Retrieved from: www.maine.gov/dep/water/wd/sandsalt/#intro.

[43] Meegoda, J.N., Marhaba, T.F., Ratnaweera, P.(2004). Strategies to Mitigate Salt Runoff from Salt Storage and Salt Truck Maintenance Facilities. *Journal of Hazardous, Toxic, and Radioactive Waste, 8(4),* 122-128.

Truck Maintenance:

Properly maintaining trucks that transport and distribute road salt can reduce salt runoff. Two practices in particular, properly loading and washing trucks, are small steps that make a big difference. Loading Trucks: In addition to storing salt on impervious surfaces, salt trucks should be loaded and unloaded on an impervious pad and in an enclosed area to prevent salt seepage into the soils and runoff into surface waters. Surrounding trucks with curbing should also be considered. Curbing directs runoff to an appropriate collection area where the salt can be gathered and returned to the proper storage area. This practice not only reduces salt contamination, but it also helps maximize product use. Washing Trucks: Trucks should be washed in bays that have sloped, impervious pads to direct runoff to a collection area for recycling or proper disposal. Michigan requires facilities to obtain prior approval from their wastewater treatment facility operator before any discharge of the wastewater to a publicly owned sanitary sewer system[44].

Issues Addressed by the BMPs

Groundwater and surface water contamination is of particular concern for individual citizens, Maine municipalities, and state government agencies. Groundwater contamination not only poses a threat to public health, but it also can cost municipal and state governments thousands of dollars in remediation costs[45]. Surface water contamination can have significant impacts on multiple types of surface waters, including vernal pools, streams, and lakes. For example, research has documented detrimental effects on the organisms living in vernal pools due to extremely high chloride levels[46]. The implementation of best management practices for salt storage and handling and truck maintenance will help prevent both groundwater and surface water contamination. Further, as previously mentioned, some of these practices help prevent unnecessary salt loss, thus reducing costs associated with wasted material.

Leaders in Salt Storage and Maintenance:

Massachusetts and Michigan are leaders in salt storage and handling practices. Both states have detailed regulations on best practices for reducing salt runoff. Listed below are some examples of their regulations and/or practices:

- Uncovered storage of salt is forbidden by Massachusetts General Law Chapter 85, section 7A in areas that would threaten water supplies. (MA)
- The Drinking Water Regulations, 310 CMR 22.21(2)(b), also restrict deicing chemical storage within wellhead protection areas (Zone I and Zone II) for public water supply wells. (MA)
- Storage on impervious surfaces such as asphalt or coated concrete that provide 1 x 10-7 centimeters per second permeability or less should also be utilized to eliminate salt contaminants from seeping to groundwater. (MI)

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[44] Salt and Brine Storage Guidance. Michigan Department of Environmental Quality. Retrieved from: www.michigan.gov/documents/deq/deq-ess-p2tas-bulksaltbrineguidance_267024_7.pdf.

[45] Rubin, J., Garder, P. E., Morris, C. E., Nichols, K. L., Peckenham, J. M., McKee, P., Stern, A., Johnson, T. O.,(2010). Maine Winter Roads: Salt, Safety, Environment and Cost. *A Report by the Margaret Chase Smith Policy Center at The University of Maine.*

[46] Karraker, N. E., Gibbs, J. P., and Vonesh, J. R. (2008). Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. *Ecology Applications, 18*(3), 724-734.

Training and Certification Programs

Best Practices Overview:

Although training and certification programs for road salt management have been used in Canada for the past two decades, they are a more recent development in the United States (US). Training and certification programs commonly include educating local municipalities and private applicators on topics such as calibration methods, material choice, application methods, and proper snow disposal, often resulting in certification. Training programs in the US and Canada have led to decreases in the amount of material used and, subsequently, reductions in total material expenses.

Notable Programs:

Many of the established training programs in the US are voluntary, occur annually, and provide grant funding to run the programs. In addition, many of these programs occur through partnerships between Departments of Transportation and engineering firms or colleges/universities. In Canada, partnerships tend to be more inclusive and include partners like the Department of Environmental Protection. These programs provide participants with a comprehensive overview of best management techniques and technologies used for winter road maintenance and the associated costs and environmental impacts.

Minnesota Pollution Control Agency (MPCA) Road Salt Education Program: MPCA's training program is one of the most developed programs in the US. Initiated in 2005 by a grant awarded to Fortin Consulting, MPCA developed a training program targeting private applicators and government officials. The program consists of one four-hour session covering topics such as the dos and don'ts of deicing and calibration methods. Training ends with a voluntary test and a voluntary commitment to apply the best management practices learned during the program. After successful completion of the program, participants receive a Level 1 training certification[47].

New Hampshire Green SnowPro Certification: Offered by the University of New Hampshire's Technology Transfer Center, this half day (four hours) course concentrates on environmentally-friendly winter maintenance practices. The training covers a variety of topics including calibration, anti-icing, brine-making, effective plowing, and salt accounting, along with various demonstrations. At the end of the session an exam is administered for Green SnowPro Certification. As of April 2011, 175 winter maintenance professionals received certification through this program[48].

Smart About Salt (SAS) Program: An award winning program based in Canada, this program was originally developed by several organizations in the city of Ottawa, Ontario. Program objectives are to maintain safe conditions, reduce salt use by promoting proactive strategies and best management practices, and reduce liability through improved snow and ice management practices[49]. To become SAS Certified, individuals must first attend an SAS training program covering key aspects of salt management. Following the training, they must then integrate

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[47] MPCA Road Salt Education Program. Minnesota Pollution Control Agency. Retrieved from: www.pca.state.mn.us/index.php/about-mpca/mpca-events-and-training/road-salt-education-program.html?menuid=&redirect=1.

[48] Green SnowPro Certification. University of New Hampshire Technology Transfer Center. Retrieved from: t2.unh.edu/green-snow-pro certification.

[49] Smart About Salt: Winter Salt Management Program. Smart About Salt Program. Retrieved from: smartaboutsaltcouncil.roundtablelive.org/Resources/Documents/SAS%20and%20Source%20Protection.pdf.

the practices learned into their winter operations. Finally, to receive the certification, he/she must verify compliance according to the program standards[50].

Economic Impact:

City of Toronto: In the spring of 2001, the City of Toronto began developing salt management practices and implemented a salt management training program to help unify practices across the city. Program planning and implementation costs totaled $60,000. After BMP and training implementation, it was estimated that mean salt usage in the 2001-2002 winter season decreased by 36,410 tons over the prior season. This reduction was estimated to save the city a total of $1,820,500. Subsequently, the city has begun to make additional investments in technologies to reduce road salt use[51].

Otterburn Park: Over the course of the 1996-1997 and 1997-1998 winter seasons the town of Otterburn Park, Quebec implemented several initiatives to decrease the amount of road salt use. Through various channels, including equipment-operator trainings, public-information campaigns, priority area identification, and equipment improvements, the town was able to decrease its salt use from 1,101 tons (1995-1996 winter season) to 294 tons over the course of four years. This decrease in salt use amounted to $151,000 in cost savings over the period while the program itself cost approximately $53,700[52] to implement.

Minnesota Pollution Control Agency (MPCA) Road Salt Education Program: A recent study by the MPCA and University of Minnesota found significant decreases in chlorides used for winter maintenance. As examined in Dakota County, during the 2008-2009 season the county used 14,175 tons of salt for 35 snow events. For the 2009-2010 season the county decreased total salt use to 9,585 tons for 27 events. The study attributed the difference in salt use between seasons to the use of magnesium chloride and the training program offered by Fortin Consulting[1].

[50] Becoming Smart About Salt: Organization and Snow Removal Contractors: Smart About Salt Program. Retrieved from: smartaboutsalt.com/Resources/Documents/SAS_OVERVIEW%20for%20contractors%20and%20facilities.PDF.
[51] Case Study #4: City of Toronto – Salt Use Reductions through Employee Training. Environment Canada. Retrieved from: www.ec.gc.ca/nopp/roadsalt/cStudies/pdfs/4%20-%20City%20of%20Toronto%20-%2004%2003%2026.pdf.
[52] Case Study # 5: Salt Reductions through a New Approach to Winter Maintenance Practices - Otterburn Park, Quebec. Environment Canada. Retrieved from: www.ec.gc.ca/nopp/roadsalt/cStudies/pdfs/5%20-%20Otterburn%20Park%20-%2004%2005%2003.pdf.

APPENDIX C – Facilitated Meetings Worksheets

April 25, 2012

Worksheet A: Salt Management: Interests and Concerns

Worksheet A was adapted for this meeting from worksheets developed by Walker (2007) and Daniels and Walker (2001). These worksheets are part of an approach called "Collaborative Learning."

Today we reviewed some of the primary social, ecological, and economic impacts of road salt. In light of these impacts and based on your experiences with winter road maintenance and/or natural resources management, please address the following questions about salt management in Maine. After recording your ideas on the worksheet, share your ideas with others in your small groups.

1) **What interests and/or concerns do you have about the risks associated with current salt application practices?**

Please consider this question from different vantage points, for example, "as an individual," "as a local or state employee," or, "as a citizen of Maine."

<u>Environmental Risks</u>

<u>Public Health and Safety Risks</u>

<u>Infrastructural Risks</u>

<u>Economic Risks</u>

<u>Other Risks</u>

2) **What concerns you most about current or potential salt management and winter road maintenance practices?**

   Of these, which are your priority concerns and why?

3) **Do you feel you have the necessary information to make decisions about salt management in your community or the state? If not, what additional information do you need?**

4) **Are there any other groups (state agencies, municipalities, contractors, university/college researchers, citizens) who share your priority concerns? If so, which ones?**

July 18, 2012

Worksheet B - Salt Management: Generating Improvements

Worksheet B was adapted for this meeting from worksheets developed by Walker (2007) and Daniels and Walker (2001). These worksheets are part of an approach called "Collaborative Learning."

Thinking about the potential Best Management Practices (BMPs) discussed today and the environmental, public safety, and economic concerns associated with road salt discussed at the last meeting, identify some policies and practices that you believe currently improve, or could improve, salt management practices in the state. *Policy or practice improvements are desirable and feasible changes to the present situation.* An improvement might be a new policy or practice, or a revision to an existing policy or practice.

1) **Which of the BMPs presented today are <u>currently</u> in place in your community or in the state? How do you see these addressing the concerns with road salt use?**

   Current Practice/Policy Description (provide details) Concern Addressed

2) **Which of the BMPs presented today might <u>potentially</u> work for your community or would you like to explore further? How do you see these BMPs addressing the concerns with road salt use?**

   Potential Practice/Policy Description (provide details) Concern Addressed

3) **Explain why your top 1-2 BMPs are desirable. How will they help improve local or statewide salt management practices?**

4) **What barriers do you anticipate might prevent you from implementing these desirable BMPs? Is there additional information you need to know prior to implementation? Who else needs to be involved to assist with BMP implementation?**

5) **Are there specific improvements on which you feel the Maine Salt Management Task Force should focus its efforts?**

APPENDIX D – Focus Group and Individual Interview Instrument
WRRI: Maine Salt Management Taskforce Focus Group and Interview Questions

Warm-Up Questions

Tell us a little bit about your job and specifically how it relates to winter road maintenance and road salt management?

Follow-up (based on first focus group): What functions do you oversee in your position?

Talk to us a little bit about your reasons for being here today. What motivated you to join us for this focus group?

Follow-up: What, if any, are some of your concerns (environmental, social, or economic) with the use of road salt in your community?

Local BMPs

As I mentioned, the taskforce is exploring best management practices that might work for Maine. As part of that process, we're trying to understand the current practices in Maine. So the next set of questions will talk about those.

Thinking specifically about your community, what are the best management practices you use for road salt application?

What specific resources, organizations, or individuals have you used to learn about road salt best management practices?

Follow-up: Will you describe the particular trainings, either in-house or with and external organization, you or your employees attend about salt BMPs?

Check time: Follow-up: Any additional things you'd like to say about local practices before we move onto BMPs?

Development of Statewide BMPs

Some of you are involved in the Maine Salt Management Taskforce. As you know, the group is exploring BMPs that can be adopted statewide with the hope of bringing those recommendations to DEP, instead of DEP telling municipalities and organizations which BMPs they should adopt.

What do you see as the opportunities and or problems with suggesting statewide BMPs?

What, if any, regional differences do you think should be considered when developing statewide BMPs for road salt?

Closing Questions

Describe for us the types of issues you would like the taskforce to address and what additional research you feel needs to be done on road salt that the taskforce could help lead or collaborate with someone else to conduct?

Is there anything else that you would like to share with us that we did not ask you?

Improving Data to Build Trust for Community Generated Knowledge of Groundwater.

Basic Information

Title:	Improving Data to Build Trust for Community Generated Knowledge of Groundwater.
Project Number:	2012ME282B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Water Quality, Education, Methods
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Progress Report: Limits to Improving the Quality of Data Generated by Student Scientists.

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Abstract

Environmental science and policy is changing to incorporate a greater use of de-centralized data collection and analysis. In particular, there is interest in a better understanding of local conditions in rural areas that rely on groundwater for drinking water. Needed monitoring data can be generated by citizen scientists. However, such data are not accepted by experts because of uncertainty and accuracy. In this study we assessed the quality of drinking water data generated by students using instrumental and simple wet chemistry analytical methods. We assessed the inherent errors associated with method accuracy, student precision, and sample variability. The goal was to establish bounds for attainable accuracy in water analyses. Methods using test kits or probes were evaluated for: pH, conductivity, chloride, hardness, iron, metals (total soluble), and nitrate. In terms of precision, all methods meet or exceeded design specifications. Given good management of student analysts, precise measurements are possible using the these methods. Method trueness was variable. However, methods used exhibited reasonable variances even when trueness was fair to poor. This indicates that a reliable transform of data is possible. The accuracy of methods meets design specifications and the potential for students to generate good quality data using these methods is high.

Critical Need

Environmental science and policy is changing to incorporate a greater use of de-centralized data collection and analysis. This trend is partly in response to the needs expressed by diverse groups having interest in a better understanding of local conditions, here specifically the focus is on local water quality. The demand for this type of knowledge is great because rural areas rely on groundwater for drinking water and overall knowledge of water quality is low. Easy to use methods and affordable new tools make it possible for citizen scientists to efficiently produce data locally. As a benefit, such data increase connections both within the community and to broader regulatory or scientific communities. These benefits may not be reciprocated because in order for the data to be accepted by experts, there must be assurances on accuracy. In this study we assessed the quality of drinking water data generated by students using instrumental and simple wet chemistry analytical methods. We assessed the inherent errors associated with method accuracy, student precision, and sample variability. The goal was to establish bounds for attainable accuracy in water analyses. If the quality of citizen-generated data are well-defined then the trustworthiness of results can be increased.

Introduction

There is a growing concern that many communities will not have adequate water resources to support future population growth due to the cumulative effects of degraded quality and quantity. The degradation of drinking water supplies are of a particular interest in rural areas where private wells are neither regulated nor tested frequently to detect changes. Nonetheless, there are agencies and individuals who need and use data in order to manage these natural resources in a sustainable manner. Successful management over a long time period must include an engaged community.

One example of a community-based research project is Groundwater Education Through Water Evaluation and Testing (GET WET!). GET WET! involves students in research to test and understand drinking water quality in their community. We use the classroom methods to illuminate what factors limit the accuracy and validity of student-scientist data. The project team collaborates with schools to have students sample and analyze their own well water for several drinking water quality analytes as a class project. Relatively uncomplicated laboratory test kits or probes are used to provide a basis for reliable and accurate measurements. Scientists, policy makers and citizens can use such a student-centered project to provide an opportunity to increase local participation and understanding of local groundwater.

GET WET! has been used to link a diverse group of stakeholders: state employees, local government officials, environmental groups, private businesses, educational institutions, students, and the local community. Project success is related to leadership by local residents who have a vested interest in the quality of their drinking water. Research has shown that relationships develop when a local school is used as the community's research center (Thornton and Leahy, 2011). Although water quality is important in the recruitment of participants, the opportunity to work with students and show science in action is motivation for others to participate. Participant's social networks lead to increased number of volunteers and event locations (Thornton and Leahy, 2012). Environmental groups are interested in the data collected and information dissemination at low cost while increasing their own connections within the community. However, including and gaining the trust of scientists in programs such as GET WET! has been a challenge. Many scientists who participated in testing stated that students and non-scientists were incapable of producing valid data (Thornton and Leahy, 2011). Informal discussions with regulatory agencies echo this sentiment; policies will not be changed based on uncorroborated student data. The fundamental concern is that student scientist data were not generated in the context of analytical laboratory quality management. It has been demonstrated that even though student-generated data have more variance than laboratory splits, the use of multiple-year results improve the statistical reliability of such water quality information for a given location (Peckenham et al., 2011).

This study addresses how to define the boundaries of certainty with student scientist data to support broader utilization of results. The involvement of students in research is an important part of science

education. Although educational goals are attained, the results of student research often are not used because of concerns with validation. Results subject to peer-review or to be used by regulatory agencies may not have the necessary documentation of quality control/quality assurance (QA/QC) procedures. Even when data are properly validated, there are problems with trust, particularly by professionals who could make use of student research results.

Background

Several successful programs have brought water-resources science into the classroom, such as the multiple-location World Water Monitoring Day (Araya and Moyer, 2006). Others sought to establish watershed science as a more fundamental part of the curriculum for K-12 (Gruver and Luloff, 2008) and college students (Borden et al., 2007). In these cases water science goals were subordinate to basic science education.

It has been recognized that participatory science education yields measurable improvements in science education outcomes (Forbes and McCloughan, 2010). Participatory science education is redefining the role of science and science education in communities (Bonney et al. 2009). Specifically: what science knowledge is needed to be a productive citizen; what science knowledge is needed by societies as a tool in decision-making; and how can communities participate in the generation of new science knowledge (Roth and Lee, 2004)? People need knowledge about natural resource systems, such as water, to contribute to policies that affect these systems (Johnson, 2003; Cockerill, 2010). This is not a simple process because the community is heterogeneous in terms of perceptions, engagement, and desired outcomes (Clay et al., 2007). However, community-based collaboration in science education is worthwhile (Rumala et al., 2011; Roth and Lee, 2004) and trust in data is a fundamental requirement.

In New England 2.3± million homes depend on private drinking water wells, but many consumers have scant information on their water quality. Absent regulations, there is little incentive for well owners to test their wells. Public information on the quality of groundwater is unknown or inaccessible to many rural populations (Kreutzwiser et al., 2010, Imgrund et al., 2011). Numerous studies have found private wells are susceptible to contamination from natural sources (e.g. arsenic, Ayotte et al., 2006) and human activities (e.g. nitrates, Nolan and Hitt, 2009). Private well owners may be unaware of these risks and lack the ability to assess these risks (Doria et al., 2009). Educating decision-makers and households about improved private drinking water management and monitoring is an unmet social need. Traditional methods of information dissemination to encourage testing reach no more than 14% of the community (Nason et al., 2011). The student/citizen-scientist approach has been documented to result in stronger community networks associated with drinking water quality (Thornton and Leahy, 2011). In particular, these networks encourage community members to test and understand their own drinking water quality. Few programs have directly addressed private well quality and GET WET! has been successful in geographically distributed locations in the eastern United States (Peckenham et al., 2011; Thornton and Leahy, 2012; Peckenham et al. , 2008).

Policy regarding water quality relies on how end-users trust the quality of the data generated. Standards for defining acceptable are both objective (strict laboratory QA/QC) and subjective (quality goal depends upon application of data). The apparent absence of strict method controls in the generation of data is often a criticism directed at student or citizen-scientist efforts (Ottinger, 2010). Methodological consistency is important for educational and other applications (e.g. GLOBE, Hamil, 1998). Student generated data and data validation were directly addressed by Lawless and Rock (1998) in an effort to document the good quality of student research. It is recognized that a process is needed to assess what constitutes reasonable quality for usable data and how to manage data from and for diverse users (Newman et al., 2011).

Methods

Students used simple instruments and test kits to analyze their drinking water for: pH, conductivity, chloride, hardness, iron or soluble metals, and nitrate. Instruments were used for pH and conductivity

with the objective to use inexpensive probes that were affordable for schools and tolerant of rough handling. Drop titration kits were used for chloride and hardness for needed accuracy and resolution. Indicator test strips were used for iron, total metals, and nitrate. Prior to 2012 nitrate was measured using a colorimetric test kit. Instruments and test kits specifications are presented in Table 1. Methods were chosen for ease of use, accuracy, sensitivity, and safety. Definitions of precision and trueness follow the ISO 5725 standard of variance (precision) and closeness to a standard value (trueness).

Methods were evaluated for repeatability, reproducibility, trueness, and precision using blanks (laboratory water), tap water, standards, spiked blanks, well water, and spiked well water. At a minimum, individual analyte analyses were run in triplicate. In addition, one to three replicate analyses were performed on 83 student samples.

Reference standard solutions were prepared for hardness, nitrate, chloride, and dissolved iron. Standards used calcium carbonate ($CaCO_3$) for hardness, sodium nitrate ($NaNO_3$) for nitrate, sodium chloride (NaCl) for chloride, and iron(II) sulfate ($FeSO_4 \cdot H_2O$) for iron. Stock solutions were prepared following appropriate Standard Methods and then diluted to working ranges using deionized water, typically in the range of 1 to 25 mgL^{-1}. Commercially prepared standards were used for conductivity and pH.

Five types of water samples were used for evaluating the methods: laboratory-grade deionized water; tap water; deionized water plus standard; well water samples; and well water samples plus standard. Analyses were performed over the range of concentrations normally encountered with student's well water samples. Tap water was from a local public water utility that uses groundwater wells, this water was filtered and chlorinated by the utility.

Statistical analyses were performed using Systat (V.12). Results were evaluated for trueness (closeness to standard value), precision (repeatability), reproducibility across methods. Statistical methods employed included: descriptive statistics, t-test, analysis of variance, and regression analysis.

Results

Method Precision. Method precision was tested by performing replicate analyses on the same sample. The number of replicate measurements made varied from five to twenty. The water samples consisted on laboratory deionized water, tap water (public water supply), and well water (private well). Since these waters were low in chloride, nitrate, and dissolved metals samples were spiked with a standard for replicated measurements. The mean value, 95% confidence interval, and the range of the confidence interval as a percentage of the mean were calculated for each set of replicates (Table 2 and 3). Three different instruments were used for measuring pH and three for conductivity as described in Table 1. In addition, two types of methods were used for metals (total iron and total metals) and two for nitrate as described in the Methods Section and Table 1.

pH. The mean values, confidence interval, and confidence interval as a percentage of the mean are presented in Table 2. The precision of the three types of pH probes tested as expressed relative to the means ranged from 0 to 2%. The precision of instrumental measures of pH were not consistent between probes. For example, probes H2 and pH55 had similar confidence intervals for deionized water while probes H2, pH55 and pH600 were similar for the well water. Probes pH55 and pH600 were very consistent in tap water with zero variances. The precision of the pH probes appears to be somewhat dependent on the characteristics of the water sample. In comparing manufacturer's precision with the experimental data the probes exceeded the design specifications of ±10% or ±0.1 units for most tests. Using well water as an example, the measured confidence interval for all three probes was in the range of ±0.06 to ±0.09 units, slightly better than the specifications of ±0.1.

Conductivity. The mean values, confidence interval, and confidence interval as a percentage of the

mean are presented in Table 2. The precision of the three conductivity probes tested exhibited considerably more variability than the pH probes. The variability, as expressed relative to the means, ranged from 0.4 to 25%. The greatest differences were observed in the low conductivity deionized water. One probe, EC59, was consistently the least precise of the three tested. Interestingly, probes C65 and EC59 exhibited similar precision with tap water while probes C65 and H1 were more similar with well water. As with the pH probes, the conductivity probes precision appears to be dependent on the type of water sample. In comparing precision with probe specifications, probe H1 exceeded specifications (±10%) while the other two probes were generally less precise than specified (±2%).

Chloride. The mean values, confidence interval, and confidence interval as a percentage of the mean are presented in Table 3. Chloride determinations were made using drop titrations with each drop corresponding to 5 mgL^{-1}. The chloride concentrations in deionized water, tap water, and well water were all <50 mgL^{-1} and replicate measurements were invariant. In order to improve the analysis of method precision an additional standard sample was made to 104 mgL^{-1} chloride. The confidence interval for the standard addition was ±7.6 mgL^{-1} which corresponded to ±7% of the mean, slightly higher than expected by method references. Given that each titrant drop in this method is equal to 5 mgL^{-1}, the low chloride samples exceeded method predictions for precision. However, less precision was observed for the spiked sample. It was observed that the end point for this method was sometimes difficult to ascertain due to interferences with color formation and color oscillations near the endpoint.

Hardness. The mean values, confidence interval, and confidence interval as a percentage of the mean are presented in Table 3. A titration method also was used for hardness measurements. The deionized water was found to have some hardness, possible due to re-carbonation by atmospheric CO_2 while in storage. However, the amount of hardness was slight. The titration steps were 17.1 mgL^{-1} and the true hardness is non-zero, but not likely the value quantified (one drop) due to the resolution of this method. The precision expressed relative to the mean values for the water tested ranged from 0 to 14%.

Iron. The mean values, confidence interval, and confidence interval as a percentage of the mean are presented in Table 3. The iron determinations were made using a test-strip colorimetric method. The well water and deionized water had no detectable iron. The tap water had trace amounts of dissolved iron and to evaluate this method further, replicated iron determinations were made on a standard sample at 2 mgL^{-1}. Confidence intervals ranged from ±0 to ±0.015 mgL^{-1}. The corresponding precision as a percentage of the means ranged from ±0 to ±9%.

Total Metals. The mean values, confidence interval, and confidence interval as a percentage of the mean are presented in Table 3. The total dissolved metals is sensitive to divalent metal ions, not just iron. This method has a lower sensitivity than the iron test method. Replicated analyses of deionized water and tap water detected no soluble metals. Metals were detected in the well water with a confidence interval of ±7.1 μgL^{-1}, this is equivalent to ±19% of the mean. The total iron and total metals determination were not similar for the well water and tap water.

Nitrate. The mean values, confidence interval, and confidence interval as a percentage of the mean are presented in Table 3. Two methods were evaluated for nitrate determinations, both based on colorimetric quantification using either ampules or test strips. In all replicates, no nitrate was detectable in deionized water, tap water, or well water. Additional replicated measurements were performed on standard samples and in all cases the confidence interval was ±0 mgL^{-1}. The precision of each method exceeded design specifications for the ranges of nitrate measured.

Method Trueness. Method trueness was assessed by performing replicate analyses of several standardized samples. The number of replicate measurements made varied from nine to fifty. The standards were made fresh before each test run. The mean value, 95% confidence interval, and the

range of the confidence interval as a percentage of the mean were calculated for each set of replicates (Table 4). The trueness of the method was compared to standard values using regression analyses across at least three standard concentrations. The correlation coefficient provided a measure of method trueness (agreement between standard value and method measurements), the coefficient of variation (R^2), and a student's t-test of equality of pooled means. Pooled means were used to simulate the variability likely to be encountered in natural samples. Three different instruments were used for measuring both pH and conductivity as described in Table 1. In addition, two types of methods were used for metals (total iron and total metals) and for nitrate as described in the Methods Section and Table 1.

Chloride. Results for trueness assessment are presented in Table 4 for number of measurements, regression correlation coefficient, R^2, and t-test on pooled means. The chloride method exhibited very good accuracy. The correlation coefficient for the regression analysis was 0.961 and the associated R^2 was 0.974. The regression coefficient was significantly different from zero at $p<0.001$. The pooled sample means (standards and measurements) were not significantly different ($p=0.424$). Even though the method resolution at 5 mgL^{-1} is modest, the trueness was very good.

Hardness. Results for trueness assessment are presented in Table 4 for number of measurements, regression correlation coefficient, R^2, and t-test on pooled means. The hardness method results showed good trueness. Based on linear regression against standard solutions the correlation coefficient was 0.885 with an R^2 of 0.990 and these results were significant at $p<0.001$. The pooled sample means were not significantly different ($p=0.170$). Given the resolution of this method with each drop corresponding to 17.1 mgL^{-1} $CaCO_3$ equivalents, the linearity was very good.

Dissolved Iron. Results for trueness assessment are presented in Table 4 for number of measurements, regression correlation coefficient, R^2, and t-test on pooled means. The accuracy of the dissolved iron method was poor over the range tested. The correlation coefficient against the standard solution was 0.562 with an R^2 of 0.799. These results are significant at $p<0.001$. These results can be interpreted to mean that the iron test under-reports iron concentrations by nearly 50%. However, when the pooled means were compared they were not found to be statistically different ($p=0.419$). This was attributed to the relatively large sample variance.

Total Metals. Results for trueness assessment are presented in Table 4 for number of measurements, regression correlation coefficient, R^2, and t-test on pooled means. The results of the total metals replicates showed that the method was not true with respect to standards over the testing range with a correlation coefficient of 0.405. However, the results had good linearity and the R^2 was very good at 0.983 with $p<0.001$. The pooled means were significantly different ($p=0.009$). This test appears to have very good repeatability (high R^2) but detected 40% of standard values. It was noted that the iron standard was sensitive to ambient oxidation and conversion of Fe(II) to Fe(III) may have contributed to the under-detection of dissolved iron.

Nitrate. Results for trueness assessment are presented in Table 4 for number of measurements, regression correlation coefficient, R^2, and t-test on pooled means. Two methods of nitrate determination were assessed for trueness. The ampule method had poor trueness and had a consistent low value with a correlation coefficient of 0.409. The linearity was modest with an R^2 of 0.855 ($p<0.001$). The pooled means were significantly different at $p=0.001$. This method had poor trueness and poor repeatability.

The second nitrate method used test strips. This method had a correlation coefficient of 0.725 with an R^2 of 0.972 ($p<0.001$). This method also under-detected nitrate but the repeatability was very good. This low variance was evident with the pooled means showing a significant difference ($p=0.008$).

Inter-Method Comparisons. Multiple pH and conductivity probes were evaluated to determine if

different types could be used by students with the expectation that results would be similar. Measurements were evaluated using analysis of variance (ANOVA). The tests using three pH probes in deionized water and tap water resulted in significant differences ($p<0.001$) (Table 5). The measurements using the student well water samples also resulted in significant differences ($p=0.038$) among the three pH probes. The use of different pH or conductivity probes in student testing will add additional uncertainty to results.

Conductivity probes were tested by replicated measurements using deionized water, tap water, and student well samples. The tests using three conductivity probes in deionized water and tap water resulted in significant differences ($p<0.001$). The measurements using the student well water samples resulted in no significant differences ($p=0.446$) among the three conductivity probes. In natural samples the conductivity variances masked the inherent variances of the probes.

Summary

In general, the trueness and precision of the test methods used in GET WET! varied by the type of test, sample characteristics, and the concentrations of the standard solutions. The analysis of pH and conductivity using probes exhibited significant differences, even though the probes were calibrated to standards before use. Although each probe was found to have reasonable precision, trueness was subject to individual instrument response. Use of the same type of instrument in testing within a classroom will reduce measurement uncertainty.

The titration-based methods for chloride and hardness had very good precision, well within the method specifications. Method accuracy was very good for chloride and good for hardness. Both methods exhibited good trueness and each had good linearity against standards. In terms of data quality, results can be expected to be accurate.

The colorimetric methods for iron or total metals were found to have very good precision and repeatability. The results exhibited poor trueness relative to standard solutions. The iron method had poor linearity and the total metals method had very good linearity with standard solutions. The total metals method can produce good quality data if corrected for trueness deviation.

The colorimetric methods for nitrate both showed very good precision. Most water well samples have no to very low concentrations of nitrate therefore evaluation focused on trace concentration detection. Both methods had fair to poor trueness. The ampoule method had poor trueness and poor linearity with standard solutions and results had unacceptable accuracy. The test strip method also had a lack of trueness. but very good linearity. This method could generate reliable data with correction for deviations from standards.

In terms of precision, all methods meet or exceeded design specifications. Given good management of student analysts, precise measurements are possible using the GET WET! methods. Method trueness was variable. However, methods used exhibited reasonable variances even when trueness was fair to poor. This indicates that a reliable transform of data is possible. The accuracy of methods meets design specifications and the potential for students to generate good quality data using these methods is high.

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Table 1. Instrument and Test Kit Specifications.

Analyte	Method	Manufacturer	Sensitivity	Resolution	Precision
pH	Instrumental	Hach	--	0.1 unit	±10 %
pH	Instrumental	Martini Instruments	--	0.1 unit	±0.1 units
pH	Instrumental	Milwaukee Instruments	--	0.1 unit	±0.1 units
Conductivity	Instrumental	Hach	10 µS/cm	1 µS/cm	±2 %
Conductivity	Instrumental	Milwaukee Instruments	1 µS/cm	1 µS/cm	±2 %
Conductivity	Instrumental	Martini Instruments	1 µS/cm	1 µS/cm	±2 %
Nitrate	Colorimetric	Chemetrics	0.25 mg/L	0.13 mg/L	±10 %
Nitrate	Test Strip	Industrial Test Systems	0.25 mg/L	Concentration Dependent	±20 %
Chloride	Drop Titration	Hach	5 mg/L	5 mg/L	±2 mg/L
Hardness	Drop Titration	Hach	17.1 mg/L	17.1 mg/L	±7 mg/L
Total Iron	Test Strip	Hach	0.15 mg/L	Concentration Dependent	±20 %
Total Metals	Test Strip	Industrial Test Systems	10 µg/L	Concentration Dependent	±20 %
Specifications are as reported by manufacturer or estimated from method specifications.					

Table 2. Method Precision Assessment of Probes.

Instrument	Analyte	Unit	Sample	Mean	Confidence Interval	Percentage of Mean
H2	pH	pH unit	Deionized Water	7.97	±0.19	2%
pH55	pH	pH unit	Deionized Water	7.03	±0.15	2%
pH600	pH	pH unit	Deionized Water	7.40	±0.00	0%
H2	pH	pH unit	Tap Water	7.93	±0.07	1%
pH55	pH	pH unit	Tap Water	8.60	±0.00	0%
pH600	pH	pH unit	Tap Water	8.70	±0.00	0%
H2	pH	pH unit	Well Water	8.18	±0.06	1%
pH55	pH	pH unit	Well Water	8.29	±0.09	1%
pH600	pH	pH unit	Well Water	8.48	±0.09	1%
C65	Conductivity	uS/cm	Deionized Water	33.4	±1.5	5%
EC59	Conductivity	uS/cm	Deionized Water	53.6	±14	25%
H1	Conductivity	uS/cm	Deionized Water	40.3	±1.5	4%
C65	Conductivity	uS/cm	Tap Water	204.3	±11	5%
EC59	Conductivity	uS/cm	Tap Water	179.8	±9.5	5%
H1	Conductivity	uS/cm	Tap Water	217.7	±5.7	3%
C65	Conductivity	uS/cm	Well Water	155.8	±0.66	0.4%
EC59	Conductivity	uS/cm	Well Water	161.3	±3.7	2%
H1	Conductivity	uS/cm	Well Water	224.5	±1.7	1%

Table 3. Methods Assessment of Wet Chemistry and Test Strips.

Method	Analyte	Unit	Sample	Mean	Confidence Interval	Percentage of Mean
Titration	Chloride	mg/L	Deionized Water	10	±0	0%
Titration	Chloride	mg/L	Tap Water	30	±0	0%
Titration	Chloride	mg/L	Well Water	10	±0	0%
Titration	Chloride	mg/L	100 mg/L Standard	104	±7.6	7%
Titration	Hardness	mg/L	Deionized Water	17.1	±0	0%
Titration	Hardness	mg/L	Tap Water	39.9	±5.7	14%
Titration	Hardness	mg/L	Well Water	58.1	±2.8	5%
Test Strip	Total Iron	mg/L	Deionized Water	0	±0	0%
Test Strip	Total Iron	mg/L	Tap Water	0.17	±0.015	9%
Test Strip	Total Iron	mg/L	Well Water	0	±0	0%
Test Strip	Total Iron	mg/L	2 mg/L Standard	2	±0	0%
Test Strip	Total Metals	µg/L	Deionized Water	20	±0	0%
Test Strip	Total Metals	µg/L	Tap Water	200	±0	0%
Test Strip	Total Metals	µg/L	Well Water	38	±7.1	19%
Colorimetric	Nitrate	mg/L	Deionized Water	0	±0	0%
Colorimetric	Nitrate	mg/L	Tap Water	0	±0	0%
Colorimetric	Nitrate	mg/L	Well Water	0	±0	0%
Colorimetric	Nitrate	mg/L	5.0 mg/L Standard	3	±0	0%
Test Strip	Nitrate	mg/L	Deionized Water	0	±0	0%
Test Strip	Nitrate	mg/L	Tap Water	0	±0	0%
Test Strip	Nitrate	mg/L	Well Water	0	±0	0%
Test Strip	Nitrate	mg/L	5.5 mg/L Standard	5	±0	0%

Table 4. Methods Trueness Assessment (a) and Probes Variances (b).

Analyte	Method	Number of Measurements	Correlation Coefficient Against Standard	R^2	p-value	t-test on means p-value
Chloride	Hach Titration	50	0.961	0.974	<0.001	0.424
Hardness	Hach Titration	15	0.885	0.990	<0.001	0.170
Iron	Hach Test Strips	12	0.562	0.799	<0.001	0.419
Metals (Total)	ITS Test Strips	9	0.405	0.983	<0.001	0.009
Nitrate	Chemetrics	21	0.409	0.855	<0.001	0.001
Nitrate	ITS Test Strips	21	0.725	0.972	<0.001	0.008

Analyte	Media	Number of Measurements	Effect	p-value
Conductivity	Deionized Water	9	Compare Probes	<0.001
Conductivity	Tap Water	9	Compare Probes	<0.001
Conductivity	Student Samples	72	Compare Probes	0.446
pH	Deionized Water	9	Compare Probes	<0.001
pH	Tap Water	9	Compare Probes	<0.001
pH	Student Samples	69	Compare Probes	0.038

Maine Information Transfer

Basic Information

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Publications

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Publications

Peer Reviewed Publications

Strock, K.E., S.J. Nelson, J.E. Saros, A. Baumann, J.S. Kahl, W. McDowell. Trends in biogeochemical recovery from acidification in the Northeastern U.S.: new insights from three decades of lake monitoring. *Environmental Science and Technology*. In prep.

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Derek Olson, Barbara S. Arter, Karen Wilson (2012). Investigating Variability of North Atlantic Alewife (*alosa pseudoharengus*) Populations by Integrating Historic Run Data with Climatic, Geographic and Landscape Data. Poster Presentation, Maine Water Conference May 14, 2013. Augusta, ME.

Other Publications

Hallsworth, R., K. Raymond, and K. Ridley. 2012. SSI Spring Newsletter. University of Maine. Solutions Vol. 1 No. 2. http://www.umaine.edu/sustainabilitysolutions/news/solutions.html

doSSIer

doSSIer is the team newsletter of Maine's Sustainability Solutions Initiative, a program of the Mitchell Center. The newsletter is published bi-weekly and provides news and updates for the SSI team. It is e-mailed to 150 participating faculty and students and posted to the SSI web site.

DoSSIer Issues No. 43 (3/12/2012) – No. 59 (2/27/2013) - 17 issues total.

News and Events

The *News and Events* newsletter goes out via email to a mailing list of over 1700 people on a monthly basis.

Conferences and Annual Meetings

Maine Water Conference 2012
The 2012 Maine Water Conference took place on March 14 at the Augusta Civic Center in Augusta, Maine. Sessions topics included river restoration, nonpoint source contaminants, groundwater management, citizen science, municipal decision-making and fisheries. Plenary speakers were Todd Norton, Washington State University, and Ken Wagner, Water Resource Services.

The Maine Water Conference is the largest water resources related conference in Maine attracting over 350 water resource professionals. It provides unprecedented opportunities to promote both the Mitchell Center's and UMaine's role in environmental research and problem-solving throughout Maine and to build stronger relationships with state and federal agencies, NGOs, and the private sector. The MWC Steering Committee is made up of key water resource stakeholders from across the state.

Sponsorship for the 2012 Maine Water Conference was provided by: U.S. Geological Survey, Senator George J. Mitchell Center and the Maine Water Institute, Maine's Sustainability Solutions Initiative, Maine WasteWater Control, Maine Geological Survey, Maine Water Utilities Association, Maine Congress of Lake Associations, University of Maine Cooperative Extension, and Maine Volunteer Lake Monitoring Program.

Public Service

Media/Press

Sustainable Maine
The Maine Public Broadcast Network (MPBN) has produced 5 episodes of the Emmy-nominated *Sustainable Maine,* featuring Maine's Sustainability Solutions Initiative, a project of the Senator George J. Mitchell Center. http://video.mpbn.net/program/sustainable-maine/ Three additional episodes are in production.

- **The Triple Bottom Line**
  The first episode of "Sustainable Maine" travels Down East to meet SSI researchers, fishermen and others who are collaborating to make sure tidal power in Cobscook Bay is developed sustainably. We then head to Central Maine, where researchers are working with family forest owners struggling to steward their land in the face of growing pressures.

- **Desperate Alewives**
  Once migrating by the millions up Maine's rivers to spawn in the spring, alewife populations have plummeted in the past hundred-plus years. That spells trouble for everything from fisheries to local economies. Can alewives be brought back? SSI researchers aim to find out. They're studying the Androscoggin and Kennebec rivers and their shared watershed to learn what might work to restore this vital link in the food chain.
- **Saving Our Lakes**
  Faculty from Colby College Departments of Chemistry, Geology, Biology, Environmental Studies and Social Sciences collaborate with local conservation groups to form interdisciplinary teams with stakeholder participation to understand the impact of landscape and lake-ecosystem changes in the development of central Maine. The Belgrade Lakes region will be used as a model because it provides a unique laboratory to understand the complex dynamics between environmental, biogeochemical, and socio-economic systems.
- **Basket Trees - Saving a Tradition**
  A tiny invasive bug, the emerald ash borer could decimate Maine's ash trees and jeopardize the livelihoods of Maine's Indian basket makers, who rely on the tree for their time-honored craft. Darren Ranco, UMaine associate professor of anthropology and Chair of Native American Programs, is leading an SSI team that brings together diverse groups to try to prevent, detect and respond to this threat.
- **Pools, Policy and People - Maine's Vernal Pools**
  Many Maine communities are facing the same dilemma: how to maintain economic viability without compromising the ecological integrity of natural resources that attract people to Maine. Aram Calhoun, UMaine professor of wetland ecology, is leading an SSI research team that uses local vernal pool conservation as a model to help communities find ways to balance economic development with natural resource conservation on private land.

Committees and Service

David Hart

- Member, Science and Technical Advisory Committee, American Rivers
- Member, Sustainable Oceans, Coasts, and Waterways Advisory Committee, Heinz Center for Science, Economics, and the Environment, 2004 – present.
- Member, President's Advisory Committee on Water Information (representing the Ecological Society of America), 2003 – present.

John Peckenham

- Board Member (New England Regional Representative), National Institutes for Water Research.
- New England Private Well Initiative – Water Quality Extension and US EPA Region 1
- Source Water Collaborative and American Water Works Association Source Protection Committee
- New Business Development – Maine Water Security LLC (managing partner), Mainely Sensors LLC (consultant), Zeomatrix (consultant)
- Penobscot River Keepers
- GET WET!
- River Flow Advisory Commission- Drought Task Force
- Maine Water Conference Organizing Committee
- Maine Water Utilities Association- Water Resources Committee
- Sustainable Water Withdrawal- Land and Water Resources Council
- Maine Waste Water Control Association- Residuals Management Committee
- Penobscot River and Bay Institute- Board of Directors
- Northern Maine Children's Water Festival
- Department of Environmental Protection-Consulting Engineers of Maine Task Force

- New England Water Quality Extension Advisory Board

Sarah Nelson

- Convener, Mercury in Acadia and northeast protected areas. In collaboration with NPS-ARD, NPS-Acadia, SERC Instititute
- Lead scientist, Acadia Learning project, 2007-present
- Steering committee member, Acadian Internship in Regional Conservation and Stewardship, 2010-present
- Steering committee member, Downeast and Acadian Inititative, 2010-present
- Maine Water Conference, Science Program Chair, 2010-present
- Acadia Web Portals working group, coordinator, 2009-2010
- Scientist-teacher liaison, Acadia Learning project, 2007-present
- MDI Water Quality Coalition student mentor, 2006-present
- Appalachian Trail Environmental Monitoring Program, Water Quality Working Group
- Coordinator, University of Maine Mercury Research Group, 2006-present
- Board member, Maine Lakes Conservancy Institute 2007 - 2010
- Maine Water Conference Organizing Committee

Workshops and Other Activities

Maine's Sustainability Solutions Initiative (SSI) at the Mitchell Center

In July 2009, the Senator George J. Mitchell Center was awarded a $20 million, five-year grant by NSF EPSCoR to support Maine's Sustainability Solutions Initiative. With SSI now heading into its 5th year, synergy between SSI and the Maine WRRI program provides important leveraging opportunities for water resource projects across the state. A key component of the SSI project is its partnership with 12 other educational institutions across Maine. All of these institutions are funded to conduct research under the SSI program – many related to water resources in Maine. WRRI Director John Peckenham acts as liaison between SSI and the partner institutions building relationships that also strengthen the WRRI program. It is also important to note that many faculty who have been funded under the WRRI research program are key collaborators on the SSI project.

SSI partner institutions include: Bates, Bowdoin, Colby, Unity, University of New England, University of Southern Maine, University of Maine at Farmington, University of Maine at Augusta, University of Maine at Presque Isle, University of Maine at Fort Kent.

Introduction to Maine's Sustainability Solutions Initiative

Producing knowledge and linking it to actions that meet human needs while preserving the planet's life support systems is emerging as one of the most fundamental and difficult challenges for science in the 21st century. There is growing consensus that traditional methods of generating and using knowledge must be fundamentally reorganized to confront the breadth, magnitude, and urgency of many problems now facing society. Maine's Sustainability Solutions Initiative seeks to transform Maine's capacity for addressing these scientific challenges in ways that directly benefit Maine and other regions. The program of research will also help Maine increase economic activity and technological innovation in ways that sustain the State's remarkable "quality of place".

Maine's Sustainability Solutions Initiative Research Projects

The following funded projects provide direct linkages with the Maine WRRI program. Opportunities for further collaborations that enhance both research programs will be actively pursued in the future.

- Protecting Natural Resources at the Community Scale: Using vernal pools to study urbanization, climate change and forest management
  Team: University of Maine
  Project range: Statewide
- Sustainable Urban Regions Project
  Team: University of Southern Maine, University of Maine
  Project range: Portland and Bangor
- Decision tools to support water resources sustainability of managed lake systems
  Team: University of Maine, University of Southern Maine
  Project range: Sebago Lake Watershed
- People, Landscape and Communities
  Team: University of Maine
  Project range: Statewide
- The Knowledge-to-Action Collaborative
  Team: University of Maine
  Project range: Statewide
- Analysis of Alternative Futures in the Maine Landscape using Spatial Models of Coupled Social and Ecological Systems
  Team: University of Maine, University of Maine School of Law
  Project range: Lower Penobscot River Watershed & Casco Bay Watershed
- Helping Communities Weather the Storms
  Team: University of Maine, UMaine Cooperative Extension
  Project range: Coastal Maine
- Mobilizing Diverse Interests to Address Invasive Species Threats to Coupled Natural/Human Systems: The Case of the Emerald Ash Borer in Maine
  Team: University of Maine
  Project range: Statewide
- The Maine Tidal Power Initiative: Linking knowledge to action for responsible tidal power development
  Team: University of Maine
  Project range: Down East Maine
- Effects of Climate Change on Organisms
  Team: University of Maine
  Project range: Statewide
- SES Synergy: Finding and Applying Best Practices in Socio-ecological Systems Modeling and Outreach
  Team: University of Maine
  Range: Project wide
- Ecological and Economic Recovery and Sustainability of the Kennebec and Androscoggin Rivers, Estuary and Nearshore Environment
  Team: Bates & Bowdoin Colleges, University of Southern Maine
  Project range: Androscoggin and Kennebec Rivers and Estuary
- Modeling Resilience and Adaptation in the Belgrade Lakes Watershed
  Team: Colby College
  Project range: Belgrade Lakes Watershed
- Sustaining Quality of Place in the Saco River Estuary through Community Based Ecosystem Management
  Team: University of New England
  Project range: Saco River Estuary
- Understanding An Insect Threat to Maine's Hemlock Trees
  Team: Unity College
  Project range: Southern & Central Maine

- Assessing the Feasibility and Sustainability of Grass Biomass Production in Aroostook County
  Team: University of Maine at Presque Isle (UMPI)
  Project range: Aroostook River Watershed
- Charting the Rangeley Region's Social-Ecological System and Identifying Community Sustainability Strategies
  Team: University of Maine at Farmington (UMF)
  Project range: Rangeley Lakes Region
- Biomass Energy Resources in the St. John Valley, Aroostook County, Maine: Landscape Implications and Sustainable Development Potentials
  Team: University of Maine at Fort Kent (UMFK)
  Project range: St. John Valley
- Evaluating Interactions Between Wild Turkeys and Maine Agriculture
  University of Maine at Augusta (UMA)
  Project range: Statewide

Senator George J. Mitchell Lecture on Sustainability
The September 25, 2012 Senator George J. Mitchell Lecture on Sustainability featured Pamela Matson, the Dean of the School of Earth Sciences and the Goldman Professor of Environmental Science at Stanford University. The title of Matson's keynote was "A Call to Arms for a Transition to Sustainablity."

Matson's research addresses a range of environment and sustainability issues, including sustainability of agricultural systems; vulnerability of particular people and places to climate change; and the environmental consequences of global change in the nitrogen and carbon cycles. With multi-disciplinary teams, she has worked to develop agricultural approaches that reduce environmental impacts while maintaining livelihoods and human wellbeing.

Dr. Matson is an elected member of the National Academy of Science and the American Academy of Arts and Sciences. She has received a MacArthur Fellowship and directs the Leopold Leadership Program. Her recent publications include *Seeds of Sustainability: Lessons from the Birthplace of the Green Revolution* and the National Research Council volume titled *Advancing the Science of Climate Change*.

2012 Northern Maine Children's Water Festival
Over 800 students and teachers from 14 middle and elementary schools all over Northern Maine convened at the University of Maine campus on October 14, 2012 for the 10th biennial Northern Maine Children's Water Festival. Water resource professionals from Maine and New England provide presentations and activities about water, wetlands, human health and aquatic life; there are water trivia quiz shows hosted by local radio and television personalities, as well as activities using music and art. This experience is provided at no cost to the participants. In fact, the festival provides funding to help schools pay the cost of transportation. The Festival goals are to teach students about the value of clean water and healthy habitats, and to provide teachers with materials and lessons that they can use for years to come. Also, many activities are aligned with Maine's Learning Results. Schools are chosen to attend on the basis of their applications, what they currently teach about water, and how they will use the Festival experience in their curriculum.

The Northern Maine Children's Water Festival is sponsored by the Maine Department of Environmental Protection, the Senator George J. Mitchell Center, Maine CDC Drinking Water Program, University of Maine Cooperative Extension and Conference Services, and Maine Sea Grant.

Mitchell Center and SSI Seminars

- **March 12, 2012** – Todd Norton, Washington State University
  Integrating Graduate and Undergraduate Curriculum Across the Disciplines Through Place-based Research

- **March 23, 2012** – Sarah Marrinan, Maine's Sustainability Solutions Initiative
  Deep-Water and Land-Based Wind Power as Substitutes: Measuring the Influences for Wind Power Support in Maine
- **March 23, 2012** – Emily Freedman, Maine's Sustainability Solutions Initiative
  An Analysis of the Economic Impacts of Cruise Tourism on Coastal Communities – a Bar Harbor Case Study
- **March 29, 2012** – David Sloan Wilson – Binghampton University
  Using Evolution to Improve Quality of Life
- **April 16, 2012** – Karen Wilson, University of Southern Maine
  Assessing marine-freshwater linkages in food webs using stable isotopes: the Penobscot System
- **October 25, 2012** – Mike Fotos, Dept. of Political Science, Yale University
  Operational Polycentricity: Sustainable Governance and Governance for Sustainability
- **November 6, 2012** – David Secord, Tides Canada
  Linking sustainability theory and practice: Lessons learned from place-based philanthropy
- **November 13, 2012** – Tom Schueler, Chesapeake Stormwater Network
  Can Urban Watersheds Be Sustainable?
- **December 6, 2012** – Bridie McGreavy, Maine's Sustainability Solutions Initiative
  K-A Workshop – Building Connections, Finding Alignment

Web Sites

The Mitchell Center hosts two Web sites, the main Mitchell Center Web site (http://umaine.edu/mitchellcenter/) and Maine's Sustainability Solutions Initiative web site. WRRI program information is available on the Mitchell Center web site and includes updates on funded projects, grant programs, and related conferences and grant opportunities. The site is updated weekly.

The SSI Web site was launched in 2009 (http://www.umaine.edu/sustainabilitysolutions/) and is designed to assist with SSI communication efforts. The site contains information covering many aspects of the initiative including current research projects, faculty and student involvement, student opportunities and recruitment materials, resources, and news and events.

GET WET!

Groundwater Education through Water Evaluation and Testing (GET WET!) is an experiential project to raise community awareness about groundwater quality and to provide data for a study of gravel mining and water quality. There are three key objective categories: science, community, and education. Since its inceptions, GET WET! has expanded to several New England States, New York, and Florida.

Scientific goals include:

- Create long-term water quality databases in towns through annual well monitoring and sampling.
- Utilize students to sample. The wells sampled are located in, over, or next to the sand and gravel aquifer.
- Include in the database: 1) Water chemistry of nitrate, alkalinity, chloride, conductivity, and turbidity. 2) Locations of wells mapped into a GIS program. 3) Operational excel spreadsheets with all information gathered. 4) Statistics and charts to graphically represent information.

Community goals include:

- Increase awareness, understanding, and interest in water resources within towns.
- Involve local citizens in the sampling, monitoring, and maintenance of water quality within their town.
- Generate a water quality database that can be used by the community to formulate productive choices in planning, management, and development.

Education goals include:

- Create an interdisciplinary study focusing on natural resources water and development.

- Employ all grades and educators involved in chemistry, geology, geodesy, mapping, GIS, statistics, computer programs, and environmental studies.
- Encourage student development in: 1) Field sampling techniques. 2) Laboratory skills. 3) Computer competence. 4) Internet research capabilities. 5) Mapping abilities in both interpolation of hard copy topographic maps and interpretation of computer based topographic maps. 6) Recognition and identification of locations by latitude and longitude on topographic maps. 7) Comprehension in terminology and function of water chemistry testing for nitrates, alkalinity, chloride, conductivity, and turbidity. 8) Understanding of why conservation and commitment to a healthy environment takes an entire community. 9) Public presentation.

Bio-sentinels of Mercury in Freshwater Ecosystems: The role of dragonflies
Mitchell Center scientist Sarah Nelson has been working with National Park staff to coordinate sampling of dragonfly larvae across the U.S. parks, leading field trips to sample dragonflies and water, and shipping samples to UMaine for laboratory analysis. A team of Old Town High School science students participated in the research from their classroom laboratory, setting up mesocosms — mini-ecosystems in the form of tanks of stream water — where adult dragonflies they captured have laid eggs. After the approximately 300 eggs hatched, the students studied how — and at what rate — mercury accumulates as the dragonfly larvae grow.

In early 2013, the National Park Service awarded Nelson another grant to expand her research on dragonfly larvae. The project will include working with Citizen Scientists in 25 parks during 2013 to help collect larvae samples in spring/early summer, and later in the summer/fall.

Maine Water Resource Research Institute at the Sustainable Water Management Conference
Maine Water Institute Director John Peckenham presented on the metrics of source water protection as part of the American Water Works Association conference held recently in Nashville. As part of the Conferences' technical workshops, Peckenham was part of a session titled, "Know Your Watershed – Source Water Protection Through Local Engagement" which discussed tools and outreach methods for protecting watersheds.

Schoodic Education & Research Center (SERC)
The Mitchell Center, represented by Sarah Nelson, has partnered with SERC and several other organizations to connect working scientists with high school teachers to provide the teachers with training in summer institutes and with ongoing support during the school year so that they can improve their ability to support inquiry-based, student-directed field research. Examples of some projects can be found on the SERC web site - http://www.sercinstitute.org/.

Acadia Learning
This program takes research issues and topics that are of interest to National Parks to teachers and schools across Maine, engaging students in useful citizen science research while providing them with enriched science education. The initiative is made of a number of interconnected projects that focus on different scientific and educational research problems. For more information see http://parkcitizenscience.org/.

Research Coordination Network: Diadromous Species Restoration Research Network
The Diadromous Species Restoration Research Network (DSRRN) is an NSF-funded network whose goal is to advance the science of diadromous fish restoration and to facilitate interactions among scientists, managers, and stakeholders. DSRRN is a joint project of the Senator George J. Mitchell Center at the University of Maine and the University of Southern Maine. Funding for the project was received from the National Science Foundation A web site for the network was established at http://www.umaine.edu/searunfish.

In the final year of the project, the DSRRN workshop, "*Using Adaptive Management to Restore the Diadromous Fish Community in Northeastern North America* " was held on January 9, 2013 at the Mitchell Center. The final DSRRN Science meeting, *"Diadromous Species Restoration Science 2013: Migration, Habitat, Species Interactions, and Management"* was held on January 10-11 at the Mitchell Center.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	4	9
Masters	4	0	0	15	19
Ph.D.	1	0	0	11	12
Post-Doc.	0	0	0	4	4
Total	10	0	0	34	44

Notable Awards and Achievements

SSI Undergraduate Student Awarded CUGR Fellowship

Michael Dandy, a junior in UMaine's Civil & Environmental Engineering Dept.,was the recipient of a Center for Undergraduate Research Fellowship at UMaine for his research project titled, Extreme Rainfall in a Changing Climate: Developing New Methodologies to Inform Infrastructure Design . Michael is an undergraduate researcher on the SSI research project, "Helping Communities Weather the Storms". His faculty advisor is project co-leader Shaleen Jain. Michael is working on understanding basic principles of hydrologic design (especially culverts) and implications of extreme storms on infrastructure vulnerability. Michael went on to present his research at the 27th National Conference on Undergraduate Research (NCUR) held at the University of Wisconsin-La Crosse on April 11-13, 2013. Michael also presented his research at the UMaine Center for Undergraduate Research (CUGR) Showcase annual event held at UMaine April 5, 2013.

SSI/WRRI Researcher Appointed Editor of International Water Journal

Shaleen Jain, SSI researcher and a PI on several WRRI projects, has been appointed as an Editor of the Journal of Water and Climate Change. The journal publishes refereed research and practitioner papers on all aspects of water science, technology, management and innovation in response to climate change, with emphasis on reduction of energy usage. The journal is a publication of the International Water Association and is available online.

Sustainable Maine Episodes Nominated for New England EMMY Awards

For the second year in a row, episodes of the Sustainable Maine, a documentary series focused on the Sustainability Solutions Initiative (SSI), were nominated for New England Regional Emmy Awards. The New England Emmy Awards recognize the best work being done in television throughout Maine, New Hampshire, Vermont, Upstate New York, Massachusetts, Rhode Island, and Connecticut. In 2012,the first two episodes, Desperate Alewives and The Triple Bottom Line were nominated. The 2013 nominated episodes include: Pools, Policies and People: Maine"s Vernal Pools , nominated for Outstanding Environmental Program; Basket Trees Saving a Tradition , nominated for Outstanding Historical/Cultural Program or Special; and Saving Our Lakes , nominated for Outstanding Societal Concerns Program.

Sustainable Maine is a partnership between the Maine Public Broadcasting Network (MPBN), Maine EPSCoR, and SSI, a program of the Senator George J. Mitchell Center at the University of Maine. The project is supported by the National Science Foundation.

GET WET!

There is a growing concern that many communities will not have the water resources to support anticipated population growth. Inadequate or degraded drinking water supplies are of particular interest in rural areas where private wells are neither regulated nor tested frequently. The Maine Water Institute has launched the Groundwater Education Through Water Evaluation and Testing (GET WET!) project, which is designed for rural communities and works with students in grades 5-12 to study drinking water quality.

GET WET! organizers and volunteers work with students to sample their own well water, which is then analyzed as a class project. Portable laboratory test kits are used to provide reliable and accurate measurements suitable for student use. The results are used to map water quality in the community and also to

encourage families to test their drinking water. This community-based research offers opportunities to teach students and the community about the connection between land use and water quality. This project generates valuable data, provides students with a new set of skills and knowledge, and improves community understanding of local groundwater and drinking water quality.

Publications from Prior Years